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Wm Wyld

*Return of my ancestor.
No 30*

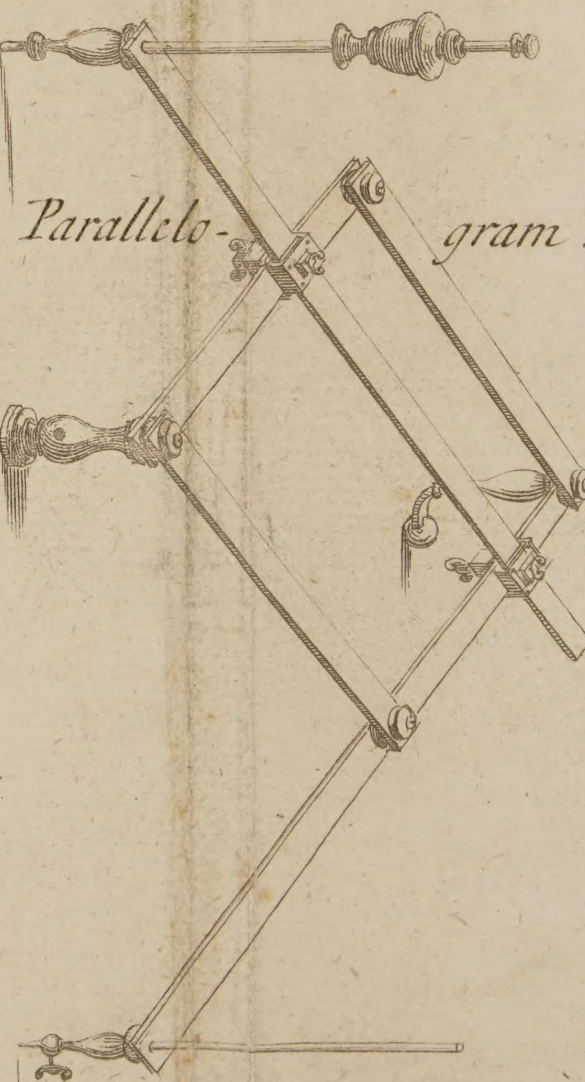
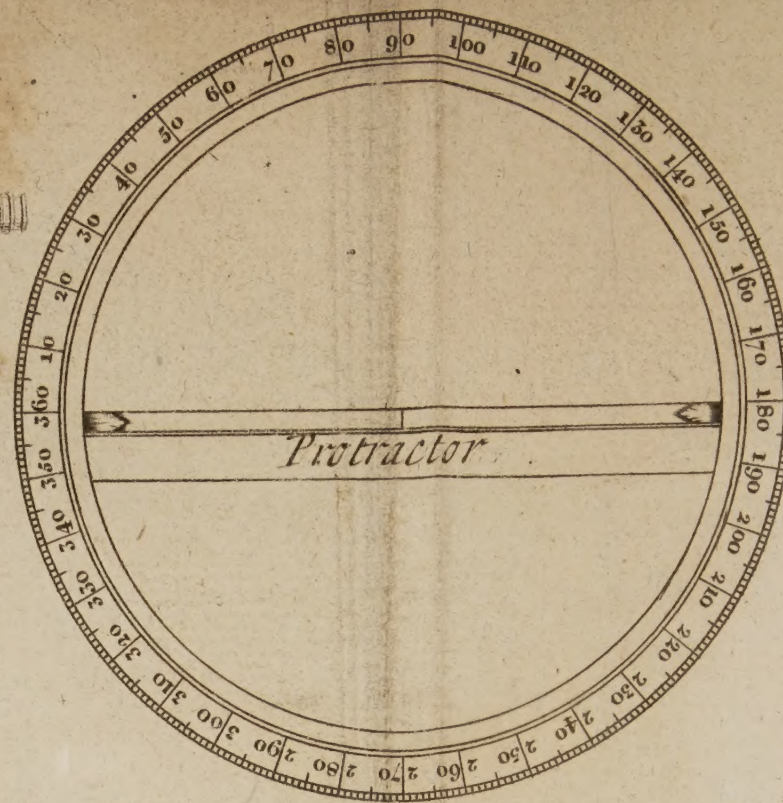


James Wyld Jun.^r

The Theodolite



Spirit Level



Parallelo-gram

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THE
Practical SURVEYOR,
OR THE
ART of *Land-Measuring*
Made E A S Y.

Shewing, by plain and familiar Rules, how to
Survey any Piece of LAND whatsoever, by the
Plain-Table, *Theodolite*, or *Circumferentor*: or,
by the Chain only.

And how to Protract, Cast up, Reduce and Divide
the same.

LIKEWISE,

An easy Method of Protracting Observations made
with the Meridian; and how to cast up the Con-
tent of any Plot of Land, by Reducing any
Multangular Figure to one Triangle.

To which is added,

An A P P E N D I X.

Shewing how to Draw Buildings, &c. in Perspec-
tive: Of Levelling; and also how to Measure
standing Timber.

By SAMUEL WYLD.

The FIFTH EDITION.

Corrected and Enlarged by a Careful HAND;
And Illustrated with several COPPER-PLATES.

L O N D O N;

Printed for W. JOHNSTON in *Ludgate-Street*.

MDCCLXIV.

Practical Surveyor

OF THE

Art of Land-Measuring

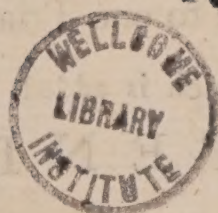
MADE IN A. S. Y.

Showing by plain and familiar Rules, how to
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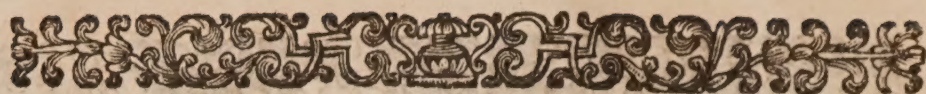
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MDCCLXXXV.



ADVERTISEMENT.

*I*N this Edition the Reader will find several Alterations and Additions which were not in the former, though in general we had the old Plan still in View. The first Chapter is entirely New; and we hope, that the Alterations which have been made in the others will be approved of. We have spared no Pains to perfect our Design, which was to render the Whole more intelligible and useful to the Practical Surveyor. The Plan of the Work will best appear from the following Table of Contents, and therefore any Account of it here will be superfluous. But we will venture to add, that, if the young Artist will take as much Pains in reading as we have taken in writing this Treatise, he will become a complete Master of the Art of Surveying.



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THE
Practical SURVEYOR.

CHAP. I.

Containing such Definitions and Problems, as are very necessary for Beginners before they enter upon Surveying.

SECT. I. *Definitions.*

I. Of a CIRCLE.



CIRCLE is a plain Figure contained under one Line called the *Circumference*, unto which all Straight or Right Lines drawn from the *Center*, are equal one to the other. A Right Line drawn through the *Center* and contained on both Sides to the *Circumference*, is called a *Diameter* : And half the *Diameter*, or any Line drawn from the *Center*

B

to

the Circumference, is called *Radius*. Thus, the Fig. 1. CADBF is a *Circle*; of which the outward Line ADBF is the *Circumference*; the middle Point C is the *Center*; the Straight Line AB is a *Diameter*, and either of the Lines CB, CA, CE, or CD, drawn from the Center to the Circumference, is a *Radius*. The Diameter as AB divides the Circle into two equal Parts, CADB, CAFB, each of which is called a *Semicircle*: And the fourth Part of a Circle, as CAD, or CBD, is called a *Quadrant*. An *Arch* of a Circle is any Part or Portion of the Circumference, as AE or ED, EDB, &c.

The Circumferences of all Circles, whether they be large or small, are commonly understood to be divided into 360 equal Parts, called *Degrees*: And each of these Degrees are again supposed to be subdivided into 60 equal Parts, called *Minutes*. So that half the Circumference contains 180 Degrees: a Quadrant is 90 Degrees; and the Bigness of every Arch, or the Proportion which it bears to the whole Circle, is expressed by the Number of Degrees and Minutes it contains. And since all Circles are divided alike, a Degree is not to be accounted a Quantity of any determinate Length, as so many Inches or Feet, &c. but is always to be reckoned as being the 360th Part of the Circumference of any Circle, without regarding in the least the Bigness of the Diameter or Radius of that Circle: And if the Arch AE contains 50 Degrees, the little Arch *a e* contains just as many; for each of these Arches have exactly the same Proportion to their respective Circles, one with the other.

Note, Degrees and Minutes are often expressed by placing an ° ' over the respective Numbers, thus 24° 30' is 24 Degrees and 30 Minutes.

II. *Of an A N G L E.*

When two straight Lines incline to one another and meet in a Point, they form what is called an **A N G L E** : the Point where the Lines meet, is called the *Angular Point* ; and the two Lines which include the Angle, are called the *Legs*, or the *containing Sides* of the said Angle. Thus, in *Fig. 2.* the Lines AC, BC form an Angle at C ; and the said Point C where the Lines meet is called the *Angular Point*.

The *Measure* of an *Angle* is an Arch of a Circle described from the Angular Point, and which is intercepted betwixt its Legs : thus, the Arch DE or *de* is the Measure of the Angle made by the two Lines CA, CB. An Angle is esteemed greater or less according to the Aperture of its Legs, or as the Arch intercepted between them contains more or fewer Degrees. And hence it may be observed, that the Bigness of an Angle doth not any ways depend upon the Length of the including Sides ; for if the Lines CA, CB, one or both be produced ever so far, or cut off ever so short, the Angle C would not thereby suffer any Change, or be made either bigger or less ; nor is it material whether it be measured by the Arch DE or *de* : for all Arches described from the Point C, and intercepted between the Lines CA, CB, contain exactly the same Number of Degrees and Minutes.

Note, When more than two Lines meet the same Point, in order to specify particularly any one of the Angles formed thereby, it is necessary it should be expressed by three Letters, whereof that at the Angular Point is usually placed in the middle : Thus, in *Fig. 3.* the Angle formed by the Lines AC, EC, is expressed by saying the Angle ACF ; and the Angle formed by EC and DC, is expressed

fed ECD or DCE : (for it is not material which Letter be placed first, so that at the Angular Point be placed in the Middle.) But when there are only two Lines meeting at the same Point, the Angle may be expressed by a single Letter, as the Angle C . *Fig. 2.*

Note, Instead of the Word *Angle*, this Character \angle is often used. *Angles* are distinguished into *Right*, *Acute*, and *Obtuse*.

A *Right Angle* is that which contains 90 Degrees, as the $\angle DCA$ or DCB in *Fig. 1.* and *Fig. 3.* An *Acute* \angle is that which is less than 90 Degrees, as ACE , ECD . An *Obtuse Angle* is greater than a right Angle, as ECB .

Note, Both *Acute* and *Obtuse Angles* are sometimes called in general Terms *Oblique Angles* without farther Distinction.

III. Of Perpendicular and Parallel Lines.

A Line is said to be *Perpendicular* to another when it forms an \angle with it of 90 Degrees, or when it stands uprightly upon it without leaning more to one Side than the other ; as in *Fig. 1.* and *Fig. 3.* the Line DC is *perpendicular* to AB ; also the Lines CB , CA , are each of them perpendicular to CD . A *Perpendicular* is the shortest Line that can be drawn from an assigned Point to a given Line ; so DC is the shortest Line that can be drawn from the Point D to touch the Line AB .

Parallel Lines, are such as are every where equidistant one from the other ; and if infinitely produced on either Side, would never meet ; as the Lines AB , CD . *Fig. 4.*

Lines are said to be *Oblique*, when they are neither *Parallel* nor *Perpendicular* to each other.

IV. Of

IV. Of a TRIANGLE.

A TRIANGLE is a Figure comprehended within three Right Lines, called *Sides*. If a Triangle hath all its Sides equal, it is called an *Equilateral Triangle*; if only two Sides are equal, it is called an *Isosecles*; and if all the three Sides are unequal, it is called a *Scalene Triangle*. Also a Triangle having one of its Angles right, is called *Right-Angled*; and all others are called *Oblique Angled Triangles*. But these Distinctions need not be regarded by a Practical Surveyor.

V. Of Quadrilateral or Four-sided Figures.

A Quadrilateral Figure having its opposite Sides parallel (and consequently equal) is called a PARALLELOGRAM, as *Fig. 5, 6, and 7*. If the Sides are all equal, and all the Angles right, as in *Fig. 5*, it is particularly called a *Square*. When the Angles are all right, and only the opposite Sides equal, as in *Fig. 6*, it is called a *Right-Angled Parallelogram*; and when the Angles are oblique, as in *Fig. 7*, it is called an *Oblique-Angled Parallelogram*.

A right Line (as *C B*, *Fig. 5*, and *6*, and *A D*, *Fig. 7*.) drawn in a Parallelogram between two opposite Angles, is called a *Diagonal*; and this Diagonal divides the Parallelogram into two Triangles which are exactly equal one to the other, *i. e.* the Triangle *A B C* is equal to the Triangle *B C D*, *Fig. 5*, and *6*; and the Triangle *A C D* is equal to *A B D*, *Fig. 7*.

All Quadrilateral Figures, which are not Parallelograms, are called *Trapezia*.

S E C T II.

Shewing how to draw Perpendiculars and Parallels; with the Description and Use of the Parallel Ruler, Protractor, and the Plotting-Scale.

- I. From any assigned Point C in a given Line A B, to erect a Perpendicular C D upon the said Line A B.
Fig. 8.

TAKE any convenient Distance, and lay the same from C on each Side, as to *a* and *b*; then having opened the Compass a little wider, from the Points *a*, *b*, describe two small Arches intersecting one another at D, and through the Point of Intersection draw the Line D C, which is the *Perpendicular* required.

If the given Point A be in, or near the End of the Line B A, as in Fig. 9, and it be required to erect a Perpendicular A C;

With any Extent A *a* describe an Arch *a d*, then lay off the same Extent from *a* to *b*, and from *b* to *d*: From the Points *b* and *d*, describe two small Arches intersecting each other at C, and through the Point of Intersection draw the right Line C A, which will be the *Perpendicular* required.

Or, if so you can't go far as *d*, lay a Ruler over the Points *a* and *b*, and mark where it intersects the Arch which was described from *b*, then through that Intersection draw the Line C A, as before

Or take any Distance and lay it somewhere from A above the given Line, Fig. 10. as to *b*; and from the Point *b* as a Center, describe an Arch greater than a Semicircle as *a A C*; then thro' the Center *b*, and the Point *a* (where the said Arch crosses the given Line) draw a right Line *a C* until it crosses the Arch in C;

C; a Line CA drawn thro' the Point of Intersection C, is the Perpendicular required. This Method may be readily put in practice by a Ruler and a Pair of Compasses, without describing any Arch; for, having taken any Extent, and laid it somewhere from A to *b*, keep fixed that Foot which is in *b*, and turn the other about until it falls upon the given Line, as at *a*: the Compasses resting in this Position, apply a Ruler close to its Legs, and keep it fixed while you turn the Foot which is in *a*, until it touches the Ruler in C; a Line drawn from C to A, will be the *Perpendicular* required, as before.

II. *From a Point given C, to let fall a Perpendicular upon a given Line B D. Fig. 11.*

From C describe an Arch that shall cut the given Line in two Places, as in *a* and *b*; then from the Points *a*, *b*, describe two Arches intersecting each other in *d*; a Ruler being laid from C to *d*, by the Edge thereof draw the right Line C D, which will be the *Perpendicular* required.

Or, from the Point given C, *Fig. 10.* draw any right Line C *a*, which bisect in *b*, then with the Extent *b c* or *b a* describe an Arch intersecting the given Line B D as in A; then C A is the *Perpendicular* required.

Note, A Perpendicular, from any assigned Point, may be drawn without using Compasses, by the Help of a small *Square* of Brass, in the Form of a Carpenter's Square; or by a Scale in a Case of Instruments, that hath a right Angle, &c. Thus, if you apply one Side of the Square close to the given Line, so as the other Side (or the Corner of it when the Point is given in the Line) may touch the given Point; a Line drawn by this Side of the Square, will be the *Perpendicular* required.

If the Corner of the Square be a little blunt, you must make an Allowance when you apply it to a Point in a Line ; and when you are drawing a Perpendicular, you must stop before you reach the given Line, and afterwards continue quite home that Part of the Perpendicular which is already drawn : but how to draw a Perpendicular by the Side of a Square, is obvious to every one.

III. *Of the PARALLEL RULER ; and how to draw a Line through any assigned Point, parallel to another given Line.*

The *Parallel Ruler* may be made of either Wood, Ivory, or Brass : It consists of two Rulers joined together in such a Manner, that if while one is kept fixed, the other be opened or drawn out, it will always keep parallel to its first Situation. These Instruments are very useful, and ready for what they are designed : They are made of various Lengths, from about 5 Inches upwards ; but for common Use a small one made of Ivory, or some hard Wood is the most hardy.

Let it be required to draw through a given Point C, a right Line parallel to another given Line A B.
Fig. 4.

Lay the Edge of the *Parallel Ruler* close to the Line A B, then keeping the lower Part of it from slipping, move the upper one till it touches the Point C, and by the Edge thereof draw the Line CD, which will be the *Parallel* required.

If the Point C happens to be farther than the *Parallel Ruler* will reach at once opening ; having opened it as far as you judge proper, keep the upper Leg fast, while you bring the lower to it ; then open the upper a Leg a second, and if it be necessary a third time,

time, &c. till it reaches the Point C, and draw the Line C D as before ; but great Care is necessary in this Operation.

The Parallel Line C D may be drawn without the Help of a Parallel Ruler ; thus,

From the given Point C, take, with a Pair of Compasses, the nearest Distance (as C a) to the given Line AB ; then with that Extent from some Point as b, near the End of the given Line describe an Arch : a right Line CD drawn thro' the Point C, so as to touch that Arch, will be the Parallel Line required.

IV. Of the PROTRACTOR ; and how to make or measure an Angle of any Number of Degrees.

The *Protractor* is usually made of Brass, and it may be either a whole Circle, or a Semicircle. The *whole Circle* is divided into 360 Degrees, all which are numbered the same Way ; *vide* Frontispiece. The *Semicircular Protractor*, I think, is the best for common Use ; and this is divided into 180 Degrees, which are numbered both Ways, as in the outer and innermost Scale of Number, *Fig. 12.* the Divisions on the Limb serving equally for both. Between these, there is another Scale of Numbers, reaching from 180° to 360° : This middlemost Scale is placed entirely for the Sake of Surveyors, but at present we shall have no Use for it, nor is it usually placed upon common Protractors : also when this is placed, the innermost is commonly omitted : but that the Instrument may be fit for all Purposes, it is best to have all three. Protractors are made of different Sizes, but those for Surveyors should be at least of six or seven Inches Diameter.

To make an Angle of any given Number of Degrees.

Lay the Center of the Protractor to the Angular Point, and bring the fiducial Edge (or the Edge passing through the Center) close to the given Line; then from that End of the Protractor which cuts this Line, count the given Number of Degrees and Minutes in the Limb, and there make a Point; a Line drawn through this Point will form the \angle required.

Example, If it be required to make an \angle at the Point C, (*Fig. 12.*) taken in the Line CA, of 45 Degrees; lay the Center of the Protractor to the Angular Point C, so that the Edge a C lies all the Way close to the given Line AC; then from this Line count 45 Degrees, and there make a Mark (with the Point of a Needle) and through this Mark draw the Line CD, which forms the \angle required: this Line forms, with the Line CB, an \angle of 135 Degrees, as is shewn by the inner Scale of Numbers. In like Manner, to make an Angle at C with the Line CB, for Instance of 34° , or $40'$: Having rectified the Protractor as before directed, count 34 Degrees (now in the innermost Scale) and for the 40 Minutes estimate as near as you can two thirds of a Degree more, and there make a Prick or Point: a Line CE drawn through this Point makes the Angle BCE $34^{\circ} 40'$; whence the \angle ACE is $145^{\circ} 20'$, as is shewn by the outermost Scale.

Note, If the given Line should not be so long as the Radius of the Protractor, it will be necessary to continue it farther; and then having placed the Center of the Instrument exactly to the Angular Point, turn it about till the Beginning of the Divisions cut the given Line. By this Means the Protractor may be adjusted more accurately than it can by trusting altogether

altogether to the fiducial Edge ; and remember always to count the Degrees in that Scale which begins on the same Side of the Angular Point that the given Line is of.

How to find the Number of Degrees contained in an Angle already made is self-evident ; for, having adjusted the Protractor to the Center and to one of the Legs of the given Angle, the other Leg (produced if need be) will cut the Degrees which the Δ contains. Thus, in *Fig. 12.* the $\angle ACD$ contains 45 Degrees, BCD 135 Degrees, BCE 34 Degrees 43 Minutes, and ACE 145 Degrees 20 Minutes.

Of the PLOTTING-SCALE.

The Sides of all right-lined plain Figures may be measured and laid down upon Paper, according to the Proportion which they bear to one another, by the Help of right Lines divided into equal Parts : These Lines are called *Scales of equal Parts* ; and a Ruler having several of these placed upon it, is usually called a *Plotting-Scale*. These Scales are made of different Sizes, and we use either of them indifferently, according to what Dimensions we would have our *Plan* or *Figure* be of, upon the Paper. These Scales are divided first into large Divisions, which are numbered 0, 10, 20, 30, &c. *Fig. 13.* the first of these between 0 and the End, is again subdivided into ten equal Parts, and this serves for a common Division for all the rest. The small Divisions may either stand for *Units*, and then the large ones will be *Tens*, according to the Numbers ; or the small ones may be *Tens* or *Tenths*, &c. and then the large Divisions will accordingly be *Hundreds* or *Units*, &c. They may also stand for *Feet*, *Yards*, *Miles*, &c. according to the different Purposes they
are

are applied to. A *Builder* would consider them as *Feet* ; a *Land-Surveyor* as *Chains* or *Perches* : and a *Sailor* would make them stand for *Miles* or *Leagues*. Most Scales are numbered at the End, which Numbers shew how many Parts of the respective Scales are contained in an *Inch* : As in the Scales A, B, and C, the Numbers 20, 30, 40. shew that so many Parts of these Scales respectively are contained in an *Inch*.

To take any Extent upon the Scale which may represent any given Number ; for Example, 56.

Set one Foot of the Compasses in 50, and extend the other to 6, reckoning from 0 towards the End, and that Extent will be 56, which may signify 56 *Feet*, or 56 *Perches*, &c. *Note*, The Division for 5 is always drawn out a little longer than the rest, for ease in counting. Let it be required again to take off 456 ; set one Foot of the Compasses in 40, which in this Case stands for 400, (and consequently the small Divisions at the End are each of them 10) and extend the other as near as you can estimate to $\frac{6}{10}$ of the Distance between 5 and 6, which Point is 56, and therefore the whole Extent between the Compasses is 456.

N. B. The Manner of using all these Scales is the same, and you may chuse either of them indifferently, as it best suits your Purpose ; but you must remember always to use the same Scale in laying down or measuring the Sides of the same Figure, and the Figures that are in the same Plan or Draught.

When the small Divisions at the End are accounted so many Tens, a Number may be taken off more accurately by such a Scale as D, called a
Diagonal

Diagonal Scale. Thus, for *Example*, to take off the Number 450.

Set one Foot of the Compasses in 4, on the Side of the Scale, which in this Case stands for 400, and carry it in that Line until you come to the 6th Parallel Line, reckoning upwards from *c* towards *a*; then extend the Compasses from that Point to the Point of Intersection of the foresaid Parallel 6, and the Diagonal 50, (reckoning the Divisions at the End of these Diagonals from *d* to *c*, each of them 10) and that Extent is 456; this may also signify $45\frac{6}{10}$, or $4\frac{56}{100}$, 4560, &c.

If a Line be given, to find how many Parts it contains, according to any assigned Scale.

Take the said Line between the Compasses, and apply that Extent to the Scale, so that one Foot being placed in one of the large Divisions, the other may fall among the small ones; the Number contained between the Feet of the Compasses, shews the Length of the Line according to that Scale. Thus a Line which measures 36 upon the Scale 20, will measure 54 upon the Scale 30, and 72 upon 40; and so upon any other Scale more or less according to the Proportion which it bears to those above mentioned.

If the Diagonal Scale be used, set one Foot of the Compasses in such a one of the large Divisions, that the other may fall among the Diagonals at the End; then carry both Feet parallel to the Side of the Scale, until that which is at the Top intersects one of the Diagonals, and the Number between the Compasses (being rightly counted according to the Directions above given) will be the Length required.

By the Scale 20, the Side *A B* of the Triangle *A B C*, *Fig.* 14. measures 335, *A C* 276, and *B C* 204: And by the Scale 40, the Sides *a b*, *a c*, *b a*

of the Triangle abc , will measure each respectively, the same with the Sides of the Triangle ABC : so that each of these Triangles may represent the same Quantity of Superficies, as suppose Acres of Land; though one upon the Paper is four times bigger than the other.

It may not be amiss here to shew, how with three given right Lines to make a Triangle; for *Example*, Let there be given these three Numbers 335, 276, and 204. Having drawn a right Line, take 335 off some Scale (suppose that of 20) and lay that Extent from A to B; then having took 276 from the same Scale, set one Foot of the Compasses in A, and with the other describe an Arch at C; from B, with 204 between the Compasses, describe another Arch intersecting the former, and to this Point of Intersection draw the Lines AC, BC.

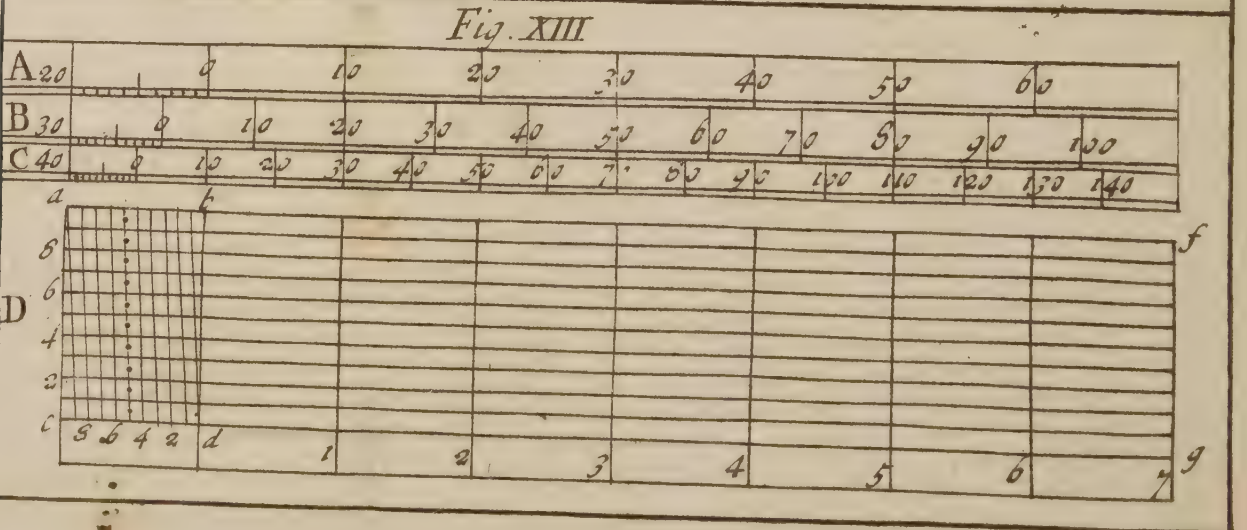
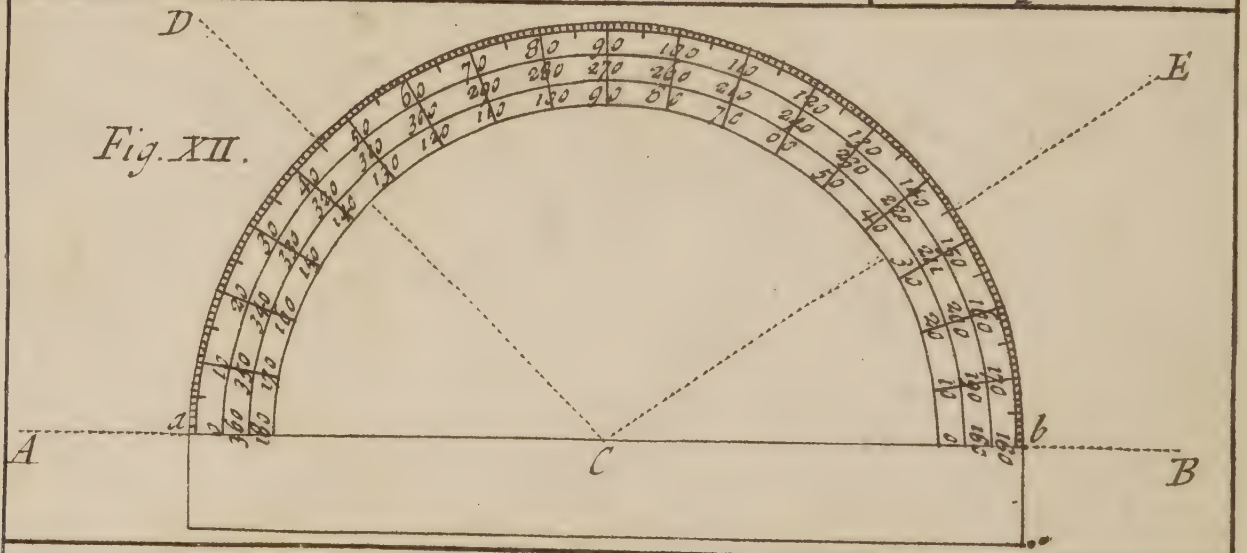
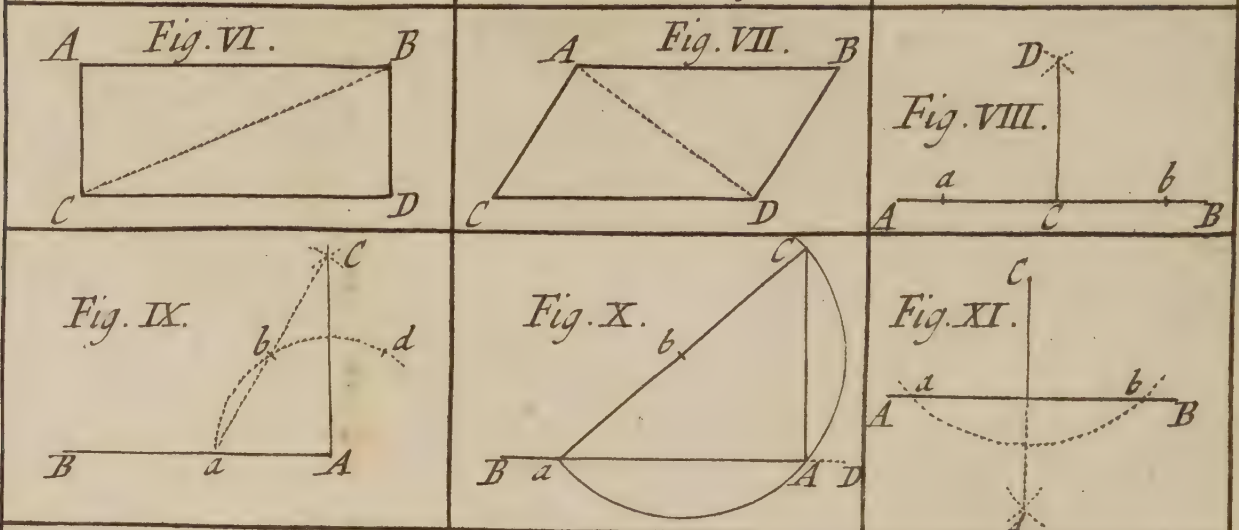
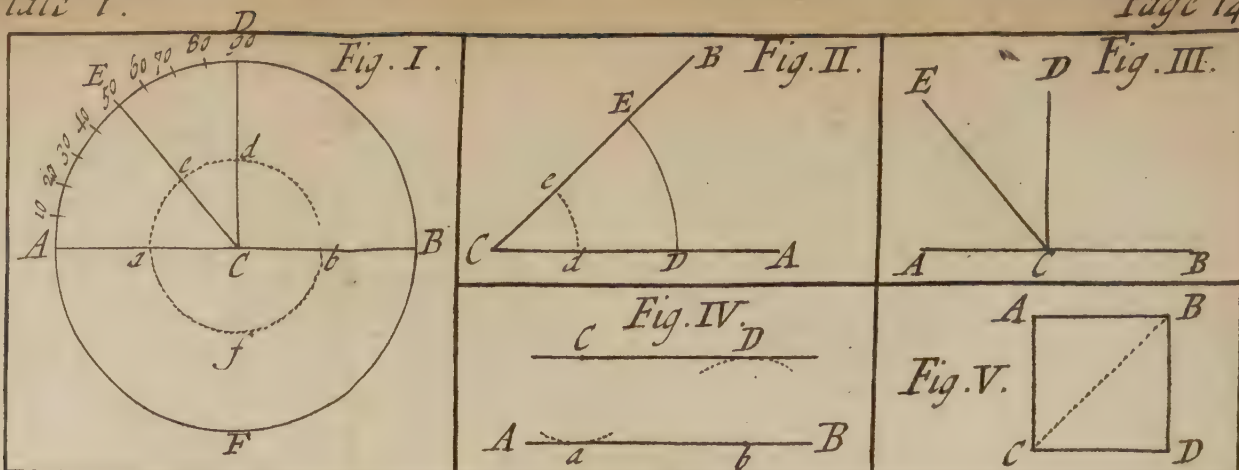
S E C T I I I.

Shewing how to find the Area or superficial Content of any plain right-lined Figure.

M*agnitudes* are distinguished into *Lines*, *Superficies* and *Solids*: And every Magnitude is measurable by some other Magnitude of the same Kind, taken as a *Standard*; as a *Line* by a *Lineal Foot*, &c. a *Superficies*, by a *Square Foot*, &c. and a *Solid* by a *Solid Foot*, &c. But our Business here is only to measure Superficies; and the Quantity or *Content* of any Superficies is called its *AREA*.

I. *To find the Area of a right-angled Parallelogram.*

Multiply the Length by the Breadth, and the Product will be the Area or Content. Thus, if in *Fig. 15.* the Side AB be five Feet, and AC 2 Feet, the Area or Contents of the right-angled Parallelogram





gram $ABCD$ is ten square Feet : Also if AB in *Fig. 16.* be 10 Feet, and AC 10 Feet, the Content of the Square $ABDC$ is 100 square Feet. If the Dimensions of the Sides be Inches, or Perches, &c. the Products will be accordingly square Inches, or square Perches, &c.

The right-angled Parallelogram is the original Figure, from whence we learn to measure all plain right-lined Figures. But before we proceed any farther, it may be proper to premise the following Lemma.

Lemma 1.

Fig. 17. Parallelograms $ABDC$, $ABFE$, which are upon the same Base AB , and between the same Parallels AB , CF , are equal one to the other, Euclid. Lib. 1 Prop. 35.

For the Triangle BDF , which is added to one, is equal to the Triangle ACE which is left out of the other. Wherefore, because the Product of AB multiplied by BD , gives the Area of the Parallelogram $ABDC$; this Product will also give the Area of the Parallelogram $ABFE$. Hence we learn,

II. To find the Area of any Oblique-Angled Parallelogram.

Let fall a Perpendicular from one of the Angles upon the opposite Side, and multiply this Side by the said Perpendicular ; the Product will be the Area required.

Fig. 18. Let the Perpendicular Ea let fall upon the Base AB be 27 Feet, and let the said Base be 34 Feet ; then the Area of the Parallelogram $ABEF$ will be 918 square Feet.

It would be the same Thing if the Perpendicular be let fall from any other of the Angles, as from F upon AB produced ; but then the Perpendicular

Fb

Fb must be multiplied by the Base AB (which is equal to ab) and not by the whole continued Line Ab .

Lemma 2.

Fig. 19. *If a Parallelogram $ABDE$ and a Triangle ABC have both the same Base AB , and are between the same Parallels AB , DE ; the Parallelogram shall be double to the Triangle.* Eucl. Lib. I. Prop. 41.

For the Triangle DCA is equal to the Triangle ACa , and the Triangle BCE is equal to the Triangle BCa . Wherefore, because the Product of AB multiplied by Ca (which is equal to DA) gives the Area of the Parallelogram $ABED$; this Product will be double to the Area of the Triangle ABC . Hence,

III. *To find the Area of any Triangle.*

Fig. 20. Let fall a Perpendicular from one of the Angles upon its opposite Side, which may be called the *Base*; then half the Perpendicular multiplied by the whole Base, or the whole Perpendicular by half the Base, will be the Area; or multiply the Base and Perpendicular together, and half that Product will be the Area. Thus, if the Perpendicular Ca be 15, and the Base AB 39, the Area of the Triangle ABC will be $292\frac{1}{2}$.

Note, The Perpendicular may be let fall from what Angle you please: thus, the Perpendicular Ab let fall upon BC produced, being multiplied by the (now) Base BC ; or the Perpendicular Bd let fall upon AC produced, being multiplied by AC , will give the same Product as before, viz. $292\frac{1}{2}$. But it is best to draw your Perpendicular from such an Angle, that it may fall within the Triangle;

Triangle, which it will always do, if it be drawn upon the longest Side: Also in acute-angled Triangles, a Perpendicular drawn from either of the Angles will always fall within the Triangle.

Note, You need not actually draw the Perpendicular, but only take with your Compasses the nearest Distance from any Angle to the opposite Side, which must be produced, if the Angle at the End of the Base be obtuse. *Note* also, when the Perpendicular falls without the Triangle, as Bd or Ab , you must take for your Base only the Side of the Triangle AC or BC , and not the whole continued Lines Ad or Bb .

IV. *To find the Area of a Trapezium, as $ABCD$.*

Fig. 21.

Draw a Diagonal, as BC , between two of the opposite Angles, and this will divide the Figure into two Triangles, each of which may be measured separately by the foregoing Article; and these two Areas will be the *Area* of the *Trapezium*.

Note, You should always draw the Diagonal between two such Angles, that the Perpendiculars drawn upon it from the two other Angles may fall within the Figure: And instead of measuring the Triangles separately, it is best to add the two Perpendiculars together; then half this Sum multiplied by the Diagonal, or the Sum of the two Perpendiculars by half the Diagonal, will be the Area required.

Thus, if BC be 46, Aa 25, 34 2)46
 and Db 34; 25

23

59

23

177

The Area of the Figure

118

ABCD is

1357


V. To find the Area of any multangular rectilineal Figure, as ABCDEFGHI. Fig. 22.

Reduce the given Figure into Triangles, by drawing as many Diagonal Lines as are necessary, which Diagonals must be drawn so as not to intersect one another; then having first found the Area of the Trapezium ABEI, find severally the Areas of the Triangles CDE, EFG, and GHI; these four Sums being added together, will be the Area of the whole Figure. A little Practice will suggest the most convenient Way of drawing the Diagonals; but which ever Way they are drawn, provided they do not intersect one another, and that the entire Figure be reduced into Triangles, the whole Area or Content will be had the same.



C H A P. II.

Shewing how to measure any Piece of Land by the Chain and the Plain-Table.

 N Acre of Land is appointed (by the Statute of 33 Ed. I.) to contain 160 square Perches or Poles; there is no Matter what Form it lies in, so that it contains 160 square Poles. But before the Plan of any Piece of Land can be laid down, or protracted upon Paper, in order to find the *Area* or Quantity of Acres it contains, we must first know the Length and Position of the several Lines which bound the same. In order to find the Position of the Hedges, Fences, or Boundaries, which inclose a Field, several Kinds of Instruments have been invented; but in this Chapter we shall consider only the *Plain Table*, as being the simplest and easiest for Beginners.

For measuring the Lengths of Lines in the Field, Surveyors make use of *Gunter's Chain*, which is certainly the best adapted for that Purpose that can be. This Chain contains in Length four Poles or 66 Feet, and is divided into 100 equal Parts or *Links*, each Link being therefore $7\frac{9}{100}$ Inches. So that one square Chain contains 16 square Perches, and ten square Chains make exactly one Acre: that is, a right-angled Parallelogram, being one Chain in Breadth and ten in Length, or two in Breadth and five in Length, is exactly an Acre. See the following Tables.

1. Table of Long Measure.

Inches	Link	Foot	Yard	Perch	Chain	Mile
Inches	7. 92	12	36	198	792	63360
feet	Links	1.515	4.56	25	100	8000
		Feet	3	16. 5	66	5280
		Yard	5. 5	22		1760
			Perch	4		320
				Chain	80	

$66 \times 12 = 792 = 1 \text{ Chain}$
 $\therefore 100 \text{ lbs} = 792 \text{ inches}$
 $\& 1 \text{ link} = 792 \text{ }^{\circ}$

2.

Chains	Links	Pts. of a Link.
1	100	
2	500	
3	333	333
4	450	
5	200	
6	166	666
7	142	285
8	125	
9	111	111

Breadth of an Acre
 Length of an Acre

3. A Table of Square Measure.

Inch	Inch	Links.	Feet	Yards	Poles	Chains	Acre
Links	62. 7264	1					
Feet	144	2295	1				
Yards	1296	20655	9	1			
Poles	39204	625	272. 25	30. 25	1		
Chains	627264	10000	4356	484	16	1	
Acre	6272640	100000	43567	4840	160	10	1

$50 = 33$
 $\times 50 \times 33$
 2500×1089

$1089 = 2500 \therefore 1 = 2,29559$

$50 \text{ feet } 3 \text{ lbs } 3 \text{ sh } 4 \text{ links}$

4. *A Table, shewing how many Chains, Links, and Parts, are contained in any Number of Feet, from 1 to 1000.*

Feet. Chain. Links. Pts. of Links. Feet. Chain. Links. Pts. of Links.

1	0	1	515	200	3	03	030
2	0	3	30	300	4	54	545
3	0	4	545	400	6	06	060
4	0	6	060	500	7	57	575
5	0	7	575				
6	0	9	090	600	9	09	090
7	0	10	606	700	10	60	606
8	0	12	121	800	12	12	121
9	0	13	636	900	13	63	636
10	0	15	151	1000	15	15	151
20	0	30	303	2000	30	30	303
30	0	45	454	3000	45	45	454
40	0	60	606	4000	60	60	606
50	0	75	757	5000	75	75	757
60	0	90	909	6000	90	90	909
70	1	06	060	7000	106	06	060
80	1	21	212	8000	121	21	212
90	1	36	363	9000	136	36	360
100	1	51	515	10000	151	51	515

The Use of these Tables is plain by Inspection, therefore particular Directions are needless.

S E C T. I.

Of the Chain, Off-set Staff, and the Arrows.

TH E Chain is used in all Manner of Business in the Field, and it contains in Length, as aforesaid, 4 Poles or 66 Feet, divided into 100 Links, each Link being $7\frac{2}{3}$ Inches. At the End

of every tenth Link is fastened a Piece of Brass, in order to count the odd Links the more readily : That which is in the Middle is a plain Piece, but the others are distinguished by Holes or Notches : the first from either End of the Chain having one Hole or Notch, the second two Holes or two Notches, &c. until they meet in the Middle, which is a plain Piece without any Mark as aforesaid : the greatest Number of Marks being four, each of which being counted from the nearest End of the Chain signifies 10 Links ; thus, *one* Mark is 10, *two* 20, *three* 30, &c. But when you have got beyond the Middle or 50, then *four* signifies 60 Links, *three* 70, *two* 80, and *one* 90. Also you may tie a large red Rag at 50 Links, and others of a lighter Colour at 25, from each End of the Chain, especially when the Grass is long.

But because of Furze, Water, Brushwood, &c. we are generally forced to measure the Station Lines in the Field, at some Distance from the Hedges or Fences ; and therefore the Breadth between the station Line and the Fence we measure by a Staff of the exact Length of 10 Links or $6\frac{6}{15}$ Feet. This is called an *Off-set Staff*, and is divided into 10 equal Parts, which are called Links, because their Use is the same with the Links of the Chain.

You must also provide two straight Staffs of about 5 Feet each, and 9 *Arrows* of small Sticks above a Foot long each ; these you may mark at the Top with Bits of red Cloth, and at the Bottom you may put small Iron Ferrils, pointed sharp at the End, that you may stick them easily into the Ground.

Note, Before you make use of the Chain, you should examine its Length with the Off-set Staff, stretching it on level Ground, after the same Manner as when you measure with it. Also a Surveyor should have by him some few odd Links, some Rings and a Pair of Pliers, that in Case of the Chain's breaking, he may be able readily to mend it.

Directions

Directions for measuring with the Chain.

Having set up an upright Staff at each of the Stations, betwixt which you are to measure, let the Leader of the Chain take the nine Arrows in his Hand, and one of the five-feet Staffs ; let him always draw the Chain tight, and let the Follower, standing at the first Station, direct him to place his Staff at the Chain's End in a right Line with the two Stations, and there let him stick one of his Arrows, and then go on.

Let the Follower, being come to the Arrow, take it up, and put his Staff in the Place thereof, and direct the Leader to place his Staff as before ; then let the Leader, standing at his Staff, look back towards the last Station, and he will see the two Staffs and the Station in one right Line, if they have directed right ; but if not, the Leader must move sideways till he brings his own Staff, the Follower's and the Station-Staff into a right Line ; and so must each direct the other, till the two Staffs and two Stations are in one right Line. And you must be always careful, that they who carry the Chain. deviate not from a straight Line ; otherwise neither the Form nor Content of the Plot can be true.

Let them thus proceed till they have measured to the Station, or till the Leader is nearer the Station than one Chain's Length ; then will the Number of whole Chains measured be expressed by the Number of Arrows pricked down, suppose 7 ; and the Leader holding the End of the Chain to the Station, the Follower will see how many Links are contained between the Station and last Arrow, suppose 60.

Now enter in the Field-Book, the Chains and Links without any Distinction between them, and

they will be 760, implying either 760 Links, or 7 Chains 60 Links; but the Links must always possess two Places after the Chains, as 7 Chains 4 Links must be written 704, and not 74; and 8 Chains must be written 800: Also as soon as you have measured each Length, enter it down immediately in the Field-Book, and never trust to your Memory; also at the End of each Length, enquire of the Leader and Follower how many Arrows each have in their Hands, and, if the Sum of the Arrows are not nine, the least measured Length is doubtful, and must be re-measured before you proceed.

When the Length is above nine Chains, let the Leader go on, and set his Staff down at the tenth, and let the Follower put his Staff in the Place of the Leader's, and give the Leader the nine Arrows, and then proceed as before; but enter these 10 Chains immediately in the Field-Book, and, if the Length be 10 Chains more, enter 20, &c.

Note, It is usual to allow 5 Links from the Stem of the Quickset Hedge, for the Breadth of the Ditch, except the Custom or Agreement is otherwise; but the Custom of the Place generally is the Surveyor's Rule.

Note, It is usual to have 10 Arrows, and then the two 5 Feet Staffs are omitted; but when the Grass is long, the Ground uneven, or the Distances between the Stations pretty considerable, the two long Staffs are very convenient for the two Men who carry the Chain to direct each other by.

S E C T II.

Of the PLAIN TABLE : And now by that Instrument to take a Plan of one or several Fields, by placing it at one or more Stations about the Middle, from whence the Angles may be seen.

THE *Plain Table* is a smooth Board made in the Form and about the Bigness of a common Sheet of writing Paper : Sometimes they are made large enough to hold an imperial Sheet. For fastening and keeping the Paper close down, a wooden Frame is fitted round the Edge of the Table. This *Frame* ought to be fitted so as to keep the Paper tight down, and likewise so as it may be easily put on and taken off ; and to prevent tearing the Paper in fastening it on, the upper Edge of the Table and the lower Edge of the Frame should be a little obtuse, and not square ; and if it be necessary the Frame may be fastened underneath, by Pins or Screws going through the Table. The Frame is usually divided into Degrees answering to a certain Point in the Table, taken as a Center ; but this is of little or no Use, and quite foreign to the Design of the Plain Table. There is commonly annexed to this Instrument a *Compass Box* with a *Needle* in it touched with a Load-stone ; but this also is of no great Use : for the Bearing of any Line may be found (which is the only Use here of the Needle) sufficiently exact by a little Pocket Compass.

The Plain Table is usually made so as to be taken to Pieces, I suppose for the Conveniency of Carriage, but, laying aside that Consideration, it would be much better in one entire Board, and then also it would serve as a very good *Drawing-Board*.

There

There is also belonging to the Plain Table an *Index*, having a *plain Sight* fixed upright at each End : In the lower Part of one Sight is a vertical Slit, and in the corresponding Part of the other is a wide Opening, having in the Middle of it a vertical Hair or String, to cut the Object when you look through the Slit in the other Sight ; and for the Conveniency of looking backwards without turning the Index, over the wide Opening in one Sight, is a fine Slit, and over the narrow Slit in the other is an Opening with a vertical Thread in the Middle as before described of the other Sight. *Note*, The vertical Threads and Slits ought to stand exactly over the fiducial Edge of the Index (which is always filed sloping from above) if produced through the Bottom of both Sights.

The Index is commonly made two Feet long, but the exact Length need not be regarded, if it be but convenient according to the Bigness of the Table. The outward Edge of the Index is commonly divided into Inches, and on the Surface betwixt the Line of Inches, and the fiducial Edge, is a diagonal Scale ; and also sometimes Lines of artificial Numbers, Sines and Tangents : But these Lines might, with as much Propriety, be drawn upon the Off-set Staff. Instead of all these, it would be better to have Scales of equal Parts of different Dimensions, and then you would always have at Hand such a Scale as would best suit your Purpose.

Underneath the Table is fastened a Brass *Socket*, which fits a Brass *Pin* fixed in the Head of a *three-legged Staff*. This Staff supports the Table at a proper Height, and the Table is fastened to it by a Screw in the forementioned Socket.

Note, You should always take Care that the Table, when you use it, be pretty nearly horizontal or level ; which you may know by applying to it

it a little Square, having a Line and Plummet fastened to the upright Side ; then by drawing out or in, one or more of the Legs of the Staff, as you see Occasion, you may rectify the Table sufficiently near for your Purpose. Sometimes to the Head of the Staff is fastened a *Ball and Socket* ; but this is rather a Detriment than of any real Use, for the Ball is subject to shake or turn horizontally ; and as there is no other Way of moving it, but by the immediate Application of the Hand, the same End will be obtained as soon and as well by moving the Legs of the Staff.

Directions for using the Plain Table.

Let *Fig. 23.* be supposed to represent two Fields or Enclosures, a Plot of which is desired ; and first of the Field *a l m o b.*

Having put your Plain Table in order, and observed the Needle to play well. (if you make Use of one) put a Sheet of fair Paper thereon, and press down the Frame, so that the Paper lies smooth ; then you may imagine the Paper on the Table to represent the Surface of the Land, and the Lines you shall draw thereon, to be the Boundaries of the respective Fields or Enclosures in some Proportion or other. If you make an Inch long on the Paper, to represent the Length of one Chain on the Land ; and if 5 Chains in Length, and 2 in Breadth, contain the Quantity of one Acre on the Land ; then 5 Inches in Length, and 2 in Breadth, shall also contain the Quantity of one Acre on the Paper.

This being premised, we will proceed to lay down upon the Paper, the Lines which enclose these two Fields, according to their just Length and Position ; which therefore shall include the same Quantity of Superficies as those on the Field, in Proportion as the Square of 1 Inch to the Square of 1 Chain.

But

But if we make half, or a quarter of an Inch, or half a Quarter, (by which the following Dimensions were laid down) on the Paper, to represent one Chain, it will be the same Thing in Effect, only the Plot will be thereby rendered less.

First, place the Table somewhere about the Middle of the Field, from whence, if possible, you can see all the Angles, as at $\odot 1$; and make a Hole in the Ground, over which by the Help of a Plummets and String, set the Center of the Table, by applying the String to the Head of the Staff. Having set the Instrument horizontally, turn it about till the Needle hangs over the Flower de Luce in the Box; (or if it is more convenient, turn the length-way of the Table to the length-way of the Plot, that it may, if possible, lie on one Sheet of Paper; and note, on a Bit of waste Paper, the Division in the Box the Needle hangs over when at rest) and then screw the Table fast. Assign on the Paper a Point, or stick a Pin at $\odot 1$, (to represent the Hole in the Ground or present Station) to which Point, apply the fiducial Edge of the Index, and turn it about, keeping the Edge close to the Point or Pin at \odot , till through the Sights you see the Hair cut a Staff or Mark, set up exactly in one of the Angles, as at a ; then by the Edge of the Index, draw an obscure Line from the Point \odot toward the Angle a , (with the Point of the Compasses or with a Pencil) without regarding the Length, so it be but long enough.

Let the Mark be left at a , and cause others to be set up round the Field, at every Angle therein, as at l, m, o, b ; to every one of which direct the Sights, and when the Hair therein cuts the Mark (keeping the Edge of the Index close to the Point \odot) draw the several Lines $\odot l, \odot m, \odot o, \odot b$.

Now see whether the Needle continues to hang over the same Point in the Box as when you first planted

planted the Table ; also lay the Edge of the Index to the Line $\odot a$, and if then the Hair in the Sights cuts the Mark at a , and the Needle hangs over the same Point as at first, you may conclude the Table hath not been moved out of its first Position, which is carefully to be observed.

In the next Place we proceed to measure the Lines $\odot a$, $\odot l$, &c. Thus, apply the Ring at the End of the Chain to the Hole under the Table, and let the Chain be stretched at Length towards one of the Angles as at a ; and when you have measured up thereto, (observing the Directions before laid down for measuring with the Chain) you will find the Length of the Line $\odot a$ to contain 3 Chains 60 Links, which note in a Bit of Paper.

Having measured the Line $\odot a$ on the Ground. take the Length thereof, *viz.* 360 Links from the Scale of equal Parts (which you judge is most convenient for your Purpose) and lay the same (on its Representative upon the Paper) from \odot to a . After the same Manner measure with the Chain the Length of the several Lines $\odot l$, $\odot m$, $\odot o$, $\odot b$; then transfer the Length of each Line on the Ground to its Representative on the Paper, making Marks where the End of each Line falls, as at a , l , m , o , b .

Lastly, join the Points a , l , m , o , b , with Ink Lines, because they should not rub off, (and for this Purpose a Drawing-Pen is requisite) as the Lines al , lm , mo , ob and ba , which constitute the Boundaries of the Field, $almo b$.

Note, It is generally the most expeditious Way to measure one Line from the Instrument to an Angle, and the next from the Angle to the Instrument ; and so backwards and forwards till all are finished, noting down as you measure them, the Length of each Line on a Piece of Paper ; then observing which Line you began with, set on its true Length on the Paper
on

on the Table, and the rest of the Lines in their Order.

A young Beginner may take the Pains to measure a-cross some Part of the Plot on the Paper, as the Distance from *a* to *o*, or from *a* to *b*, with his Scale and Compasses ; then measuring the same Distance on the Ground with the Chain, he will find them both exactly to agree, if the Plot be truly laid down.

Having finished this Field, cause a Staff to be set up with a Paper thereon in the next, in a Place from whence you can view all the Angles ; but if such a Station cannot be found, chuse the most convenient, as at $\odot 2$.

The Table standing at $\odot 1$, in the Field *a l m o b*, in the same Position as at first, (which it must do, or the Plot of the next Field cannot be truly laid down in respect of the last) lay the Index to the Point \odot , and turn it about thereon, till the Hair in the Sights cuts the Staff or Mark in the next Field at $\odot 2$; and holding the Index fast in that Position, draw a Line by the Edge thereof from $\odot 1$, towards $\odot 2$ in the next Field, and take care to continue it long enough : then remove the Table, and place a Staff with a Mark thereon, in the Hole over which the Center of the Table was placed, and measure with the Chain the nearest Distance between $\odot 1$, in the Field *a l m o b*, and $\odot 2$ in the next Field (drawing the Chain through the Hedge in a straight Line) and set on the Distance 621 (by the Help of the Scale and Compasses) from $\odot 1$ to $\odot 2$.

Now take away the Staff, and plant the Center of the Table over the Hole, in which the Staff stood at $\odot 2$, and sticking two Pins, or the Points of two small Needles in $\odot 1$, and $\odot 2$: apply the Edge of the Index thereto, so that it may lie exactly on the Line $\odot 1$, $\odot 2$; and keeping it in this Position, turn the Table about till the Hair or Thread in the Sights cuts the Staff or Mark in the last Field ; then screw
the

the Table fast that it stir not out of its Position, till you have finished the Observations in this Field : (But observe to turn that Part of the Table marked with $\odot 1$, towards its Representative in the last Field.)

When the Needle hath settled, and is at rest, observe whether it hangs over the Flower-de-Luce or same Division in the Box, as at $\odot 1$ in the last Field; which it will do if you have made your Observation justly, and the Needle be good ; and if you were to move the Table to never so many Stations, the Needle will still point to the same Division in the Box, which you should carefully observe ; because the removing the Table from one Station to another is the greatest Difficulty in this Way of Surveying.

Having caused Marks to be set up in so many of the Angles in this Field, as you can conveniently see, from the present Station, as at k, i, b, g , lay the Index to the Point $\odot 2$, and direct the Sights to k, i, b, g , drawing Lines by the Edge of the Index towards every one of them ; then measuring the Length of the several Lines $\odot k, \odot i, \odot b, \odot g$, with the Chain, set on the several Lengths of these Lines on the respective Lines on the Paper (as before directed) marking the Points k, i, b, g , where the Ends of the Lines fall from \odot ; lastly, join the Points lk, ki, ib , and bg , with Ink Lines, and they will be the Bounders of so much of the present Field, as you can conveniently see from this Station.

But there is no Occasion to measure to the Angles l or m with the Chain, except that it may be some Satisfaction, as aforesaid, to see the Lines on the Paper and those on the Ground to agree.

Observing the former Directions for removing the Table, let it be placed in its true Position at $\odot 3$ in this Field ; then direct the Sights to the Angles f, e, d, c , and when the several Distances from $\odot 3$, to f, e, d and c , are set on the Paper, join the
Points

Points $g f, f e, e d, d c$ and $c b$, with Link Lines ; so is the true Plot of these two Fields $a l m o b$, and $l k i b g f e d c l o m$, laid down on the Paper in such Proportion as the Scale you made use of is to the Chain.

But observe that if the Hedge $b c$, had been so thick, that from $\odot 3$, you could not have seen the Angle d , or other Obstruction had hindered your Sight or Measuring thereto. you must have removed the Table to another Station ; but when you can (as commonly you may) by holding aside the Boughs or otherwise, see the Mark, and by drawing the Chain through the Hedge, measure the Line from $\odot 3$, to the Angle d ; it is better not to remove the Table : For the fewer Stations you make, the Work will be easier done, and also more truly laid down.

It would be needless to give Directions how to survey a Field from a Station taken in any Angle thereof, from whence the rest may be seen ; as if it had been more convenient, in the Field $a l m o b$, to have planted the Table at the Angle a , the Sights must have been directed from thence to the rest of the Angles l, m, o, b ; and the Lines measured on the Ground, from a to l, m, o and b , whose Length laid down on the Paper from a would give the same Points l, m, o, b , as if the Station had been in the Middle of the Field ; and the Bounders being drawn, they would be in the same Position as before.

If you would draw a Meridian, or a North and South Line through the Plot ; turn the Table about, till the Needle hangs over the Flower-de-luce in the Card, and laying the Index at right Angles to the long Sides of the Table, draw a Line close by the Edge, which shall be a Meridian Line ; and if you cross this Line by another at right Angles, that shall shew the East and West Points.

Note,

Note, Having removed the Table to a new Station, if the Index be laid close to the Line drawn betwixt that Station and the last, the Table may be thereby rectified to a greater Exactness than can be done by the Needle, which at best is uncertain and liable to be out of order; and, as before intimated, the Needle is not properly an Appendage of the Plain Table, though we have here all along supposed it annexed to this Instrument; for the Sake of complying with Custom.

S E C T III.

Directions for casting up the Content of any Piece of Land.

THE next Thing that lies before us is the Manner of calculating the Quantity of the Superficies, or the *Area*, enclosed by the Lines on the Paper, as they represent the Boundaries in the Field; that is to say, how many Acres and Parts of an Acre are contained therein.

The Manner of finding the *Area* and *Content* of any plain right-lined Figure hath been already laid down in SECT. 3. of CHAP. I. It hath been also shewed, that the Method of finding the Content of all plain right-lined Figures is deduced from the right-angled Parallelogram, the Area of which is found by multiplying the Length by the Breadth: Wherefore because 10 square Chains make 1 Acre, if the Side AB of the right-angled Parallelogram ABCD (*Fig. 15.*) be 5 Chains, and AC 2 Chains, the Area of ABCD is just 1 Acre. Also if the Sides of the Square ABCD, *Fig. 16.* be each 10 Chains, the Content of the said Figure will be 100 square Chains, or 10 Acres.

D

But

But because almost all Fields to be met with in Surveying are irregular, and bounded with several unequal Lines, we must first take the Plot thereof by some Instrument, and lay it down on Paper; then, by drawing diagonal Lines, we may reduce the Figure into Triangles, &c. *Vide Fig. 24.*

The Lengths of the several Lines in the Field are usually set down in Links, without distinguishing them into Chains and Links, as 6 Chains 54 Links is writ 654, which signifies 654 Links; for as a Link is the lowest Denomination, and the only one used, there is no Necessity for writing down the Word *Links*. And as a Chain contains in length 100 Links, therefore in 1 square Chain there are 10,000 square Links, and 100,000 square Links in an Acre. Wherefore having the Content of a Field given in square Links, if we cut off 5 Figures to the right Hand, what is left on the other Side (if there be any) will be Acres. Thus, if a Field contains 1654321 square Links, the Area thereof will be 16 Acres and $\frac{54321}{100000}$ Parts of an Acre, or 16.54321 Acres. The Chain is made 66 Feet in Length, and divided into 100 equal Parts on Purpose, to save the Trouble of Division in computing the Number of Statute Acres.

Note, The Content of every Field is usually set down in *Acres, Roods* and *Perches*. An *Acre* contains 4 *Roods*, and one *Rood* 40 square *Poles* or *Perches*. Wherefore, the Content of a Field being given in square Links, and having found the Number of Acres contained therein as above, multiply the 5 Figures, which were cut off by 4, and from this Product cut off again 5 Figures, what is left will be Roods; then the Remainder so cut off being multiplied by 40, from this last Product also cut off 5 Figures, and those on the left Side will be Perches, which is the lowest Denomination usually set down of the Contents of Land.

To.

To find the Number of Acres contained in 1654321 square Links, the Operation will stand thus :

A. 16.54321

4

R. 2.17284

40

P. 6.91360

Acres Roods Perches.

Ans. 16 : 2 : 6 or rather 16 : 2 : 7 because the 91360 make almost another Perch.

To find the Content of any Piece of Land, the following is a GENERAL RULE.

First reduce the given Figure into Triangles, then measure the Bases and Perpendiculars falling upon them, of each Triangle, and multiply severally the said Bases by the Half of their Perpendiculars, or the whole Perpendiculars by half the Bases, and the Product will be the Contents of the several Triangles in square Links. Add the Contents in Links of each Triangle together, and the Sum will be the Content of the whole Field in square Links, which you may reduce into Acres, Roods and Perches, as before directed.

Thus, in *Fig. 24.* the Area of the Triangle *l m o* (whose Base *l o* is 660, and Perpendicular *m y* let fall upon it from the opposite $\angle m$ is 252) is 83160, which may be found either by multiplying half 660 by 252, or 660 by half 252.

$$\begin{array}{r}
 252 \quad 126 \\
 330 \quad 660 \\
 \hline
 7560 \quad 7560 \\
 756 \quad 756 \\
 \hline
 83160 \quad 83160
 \end{array}$$

The diagonal Line lb divides the Trapezia $loba$ into two Triangles, lob and lba , which might be separately cast up as the Triangle lmo ; but the quicker Way is to add the two Perpendiculars oz and ax together, and by that Sum multiply the Line lb , which is a common Base to both Triangles, and halve the Product for the true Content of the Trapezia. See the following Work.

Base 660— lo	Perp. 290— ax
Perp. 252— my	Perp. 272— oz
<hr/>	<hr/>
1320	562 Sum
3300	Base 800— lb
1320	<hr/>
<hr/>	449600
166320	
166320	} Product.
449600	
<hr/>	
615920	double Content.
<hr/>	
Acres — — 3.07960	true Content.
	4
<hr/>	
Roods — — .31840	
	40
<hr/>	
Poles — — 12.73600	

Acres

Acres Roods Poles Parts of a Pole.

3 : 0 : 12 : $\frac{73600}{100000}$

The Base $l o$, multiplied by the Perpendicular $m y$, produces 166320, which is double the Content of the Triangle $l m o$ in square Links. Also the Perpendicular $a x$, added to the Perpendicular $o z$, makes the Sum of both 562, which multiplied by 800, the common Base to both Perpendiculars, produces 449600, which is double the Content of the Trapezia $l o b a$ in square Links.

Therefore (for avoiding Fractions) the double Content of the Triangle $l m o$ 166320, added to the double Content of the Trapezia $l o b a$ 449600, gives 615920 the double Content of the Field $al m o b$ in square Links, the half of which (*viz.*) 307960 is the true Content of the Field $al m o b$ in square Links, which reduced into Acres, &c. as before directed, gives 3 Acres, 12 Poles, and a little above half a Pole, for the true Content of the Field $al m o b$; but the Parts of a Pole are seldom regarded.

In the same Manner the Field $b c d e f g h i k l m o$, *Fig. 24.* being divided into Trapezias and Triangles, add both the Perpendiculars of each Trapezia together, and by that Sum multiply the Diagonal or Base: Also multiply the Base of each Triangle by the Perpendicular, and set the Product of each Trapezia and Triangle in an orderly Manner, one under another, and add them altogether into one Sum, the half of which Sum will be the Content of the Field in square Links, which reduce into Acres, &c. as aforesaid.

But remember to measure the Bases and Perpendiculars by the same Scale that the Plot was laid down by, and contrive to reduce the Field into as large Trapezias and Triangles as possible; for the fewer you make, the exacter will the Work be cast

up; and draw the Base-lines neat and small, and exactly from Angle to Angle. You need not actually draw the Perpendiculars, but only take the nearest Distance from the opposite Angle to each Base, which may be readily done thus: Set one Foot of the Compasses exactly in the angular Point, and extend the other till it touches the Base; then turning it about, if it cuts the Base, observe the Middle, as near as you can guess, between these two Points; the Distance betwixt this middle Point, and that wherein the other Foot of the Compasses stands, will be the Length required, to as great an Exactness as you could measure it, if the Perpendicular had been drawn.

Note, You should always make use of as large a Scale, as the Bigness of your Plot will admit; and if you use a diagonal Scale, the Lengths of the several Lines may be laid down and measured on the Paper to a greater Exactness.

S E C T. IV.

Shewing how to make the Plot of any Field or Enclosure, on the Paper fixed on the Plain Table, by going round the same, and taking Offsets to the Bounders, &c.

THE former Method of planting the Table at one Station or more, in the Middle of the Field, and measuring from thence the Distance to every Angle, is easiest for a Beginner, but is not convenient in many Cases; because he may be hindered by Furze, Water, &c. from measuring the Lines to all the Angles; and in many Fields where the Fences are as irregular as the Side *ae* in the Field, *Fig. 25.* he will be obliged to measure a great Number of such Lines.

'Tis therefore best to plant the Instrument at the most remarkable Angles, and measure round the Field; for by this Method all Sorts of Land may be measured (so the Plan be not too large for one Sheet of Paper) either within or without the Plot, as Convenience shall determine.

Note, This Mark \odot always represents a Station, a prick Line represents the Station Line, and ——— a black Line the Boundary.

Let *Fig. 25.* represent a Field to be plotted by the Plain Table.

First, set up a Mark at *a*, and draw a Line on the Table, to represent *ab* in the Field; then measure the Distance to the Hedge from \odot 20 Links, which set from \odot to *f*; also measure the Distance from \odot *a*, to \odot *b*, 840 Links, which set on the Line *ab*.

Having drawn the Line *ab*, place the Table at *b*, and lay the Edge of the Index close to the Line *ab*, and turn the Table about till you see the Mark at *a*, and there screw it fast; then turn the Index about on *b*, till you see a Mark at *c*, and draw *bc*, with the Point of the Compasses, or a black-lead Pencil; also direct the Sights to the Barn, and draw the obscure Line *bz*, not regarding its Length so it be but long enough.

When the Needle hath settled, take Notice what Division in the Box it points to, for to that Division it will point at every Station through the Plot, if your Work be true, and the Needle good, as aforesaid; but because it is not convenient to trust to the Needle when we can do without it; I shall here lay down a surer Way to correct an Error, before it is communicated to the following Part of the Work.

In the next Place, measure the Distance from \odot *b* to the Hedge 17 Links, which set from \odot to *g*, and draw the Boundary *fg*; also measure the Distance

from \odot to b , which set on the Paper from \odot to b , and continue the Bounder fg , in a strait Line, as you see in the Field.

Remove the Table from b , and set up a Staff with Paper thereon in the Hole, over which the Center of the Table stood, according to former Directions, and measure with the Chain from b towards c ; but when you come over-against the Bend in the Hedge at i , measure the Distances from the Chain Line bc to that Bend 7 Links, which set from the Chain Line bc to i ; and draw the Boundary ib , through b , till it cuts the Boundary fg , constituting that Corner of the Field. Measure on to c 620 Links, which set from b to c .

The Reason why we made the Station b , so far from the Corner, is to avoid planting the Instrument too often; for if we had continued the Station Line ab into the Corner, we must have made another Station at i , otherwise we could not see to the Angle at c ; for the fewer Stations we make, the exacter will be the Work, as aforesaid.

Now in order to examine the Length of bc , and also its Position in respect of ab , do thus: Plant the Instrument at c , and lay the Index on the Line bc , and by turning the Instrument about, direct the Sights to b , and there screw it fast; then turn about the Index on the Point c , towards the Mark at the Angle a , in the Field, and if the Edge does not cut the Point a in the Table, the Line bc is false, either in Position or Length, and therefore must be corrected before you proceed.

The Line bc being truly laid down, and the Table standing at c , in the same Position, lay the Index to the Point c , and turn it about thereon, till the Hair in the Sights cuts the Mark at d , and draw the Line cd ; also direct the Sights to the Middle of the Barn, the Index being turned about on the
same

same Point *c*, and draw the obscure Line *c x*, crossing the other obscure Line *b z*; so shall the Point of Intersection determine the Situation of the Barn in the Middle of the Field, which you may prove by measuring on the Ground thereto, from any Part of the Field.

Next measure the Distance from the \odot at *c* to the Hedge 6 Links, which set from \odot to *k*, and draw the Boundary *ik*, continuing the Line through *k*; also measure the Distance to the other Hedge *c l*, from $\odot c$, 15 Links, which set off to *l*.

Remove the Table from *c*, and place a Mark there, and measure the Distance from *c* to *d*, 481 Links, which Distance set on the Line *c d*; then plant the Table at *d*, and having laid the Index on *c d*, turn the Table about till you see the Mark at *c*, and then screw the Instrument fast.

Next examine the Length and Position of *c d*, in respect of *b c*, as before directed; then turning the Index about on *d*, direct the Sights to *e*, and draw the Line *d e*; set off the Distance from $\odot d$ to the Hedge at *m* 10 Links, and from *m* draw the bounding Line *ml*, continuing it strait through *l*, till it crosses *ib*, as you see it do in the Field.

Leave a Mark at *d*, and plant the Table at *e*, having first measured the Length of *d e* 364 Links, which set on its proper Line from *d* to *e*; on which Line *d e* lay the Index, and, turning the Table about till you see the Mark at *d*, there screw it fast; and having proved the Line *d e* to be truly laid down in respect of *c d*, turn the Index about on *e* till you see the Mark *aia*, and draw the Line *e a*, which will cut through the Point at *a*: Also direct the Sights to the Angle *p*, and draw $\odot p$: and to *q*, drawing $\odot q$ on the Paper.

Then

Then measure with the Chain the Distances $\odot p$ and $\odot q$, setting those Distances on their proper Lines, and draw the Boundary $p o$, and $q p$.

Now measure on the Line $e a$, and when you come against the Bend in the Hedge at r , measure the Distance from the Chain Line $e a$ to that Bend 8 Links; which set on the Paper to r , and draw the Boundary $q r$.

In the same Manner measuring on the Line $e a$, set off the Distances from the Chain Line to the Angles in the Bounder s and t , and draw the Boundaries $r s$, $s t$, and $t f$, which crosses the Line $g f$, near f ; and when you have measured the Line $e a$, on the Ground, you will find it of the same Length as that before drawn on the Paper.

If the Distance from the Station to the Bends in the Hedge be great, 'tis the safest Way to plant the Center of the Table over the Station Line, as at w ; and, laying the Index on the Line $e a$, direct the Sights to e , or a , by turning the Table about, and in that Position screw it fast; then direct the Sights to the Bends in the Hedge, as, to s , or t , drawing Lines towards them, and setting off the Distances in the same Manner as is done from $\odot e$.

In order to examine the Lengths and Positions of each Line before you proceed on to the next, if you do not think it convenient to leave Marks at all the Stations round the Field; if you turn about the Index on the Point, representing the present Station, till you see any one of the Marks before laid down, and if the Edge of the Index cuts that Point on the Paper, your Work is right; so you might have left a Mark at the first Station a , and by that prove the Lengths and Positions of all the other Lines, as well as by the last but one you passed by.

But

But if you could not see the Mark at *a*, at all the other Stations, you may make use of any other Mark, as some Part of the Barn ; or you may set up a Mark in some convenient Place, from whence you can see all the Angles.

But if the Mark you last used is at too great a Distance from you, or lies almost in a strait Line with that you last laid down ; then use some other Mark in its Stead, whose Position you have before found at one of the foregoing Stations.

Or, instead of a Mark thus set up, you may use any remarkable Tree, Steeple, &c. that is not at too great a Distance from you, whether it be in the Land you are then surveying or not.

How to measure an inaccessible Distance.

Lastly, in the same Manner as you found the Position of the Barn in the Middle of the Field, *Fig. 25.* you may measure any other inaccessible Distance ; so if the Barn was so situated that you could not come nearer thereto, by reason of Water, or other Impediments, than the Line *b c*, yet you would know its Distance from *b* or *c*.

The Instrument being planted at *b*, and the Sights directed to a Mark at *c*, and also to the Barn ; and the Lines *b z*, and *b c*, drawn on the Paper as before directed ; then the Instrument being removed from *b*, and planted at *c*, and the Sights directed to a Mark left at *b*, and also to the Barn ; and the Line *c x*, also drawn on the Paper, cutting the other Line *b z* : Then shall the Point of Intersection determine the Distance of the Barn from *b* or *c*, which you may find by measuring from *b* or *c*, or any other Part of the Line *b c*, by the same Scale with which you laid down the Line *b c*.

But it is convenient to make the Stations *b* and *c* at such a Distance from one another, that the Angle

at

at the Point of Interfection may not be too Acute, lest you be not able to distinguish nicely the Point of Interfection.

If *Fig. 25.* was a Wood, so that you could not measure the Station Lines within, you may as well make them on the Outside; for the Plot will be the same, only the small Pieces of Ground between the Station Lines and Boundaries are excluded by the Boundaries from being any Part of the Plot. Particular Directions in this Case are needless; *see the Figure.*

When you are about to measure a Plot of Land, and in doubt whether it will lie on one Sheet of Paper, you may place a Line or two cross the Plot, as you walk about to chuse the most convenient Stations (reckoning so many Steps to a Chain, as you find by Experience carries you a Chain's Length) and thereby guess what Scale to make use of.

It is also convenient to make a particular Remark at the first Station in each Field, that you may readily find it when you come round to it again, in order to close the Plot.

Also as soon as you have drawn the Plot of a Field, it is necessary to write the Name somewhere in the Middle thereof.

There is another Way of Plotting a Field by the Plain Table (though scarce fit for Practice) by measuring one Line only, which in short is this:

Plant the Table at *a*, *Fig. 26.* and direct the Sights to the several Angles round the Field, keeping the Index close to the Point *a*, and by the Edge thereof draw a Line towards every Angle; then place a Staff at *a*, and plant the Table at the other Station *b*, measuring the Distance between the two Stations, which Distance set on the Line *a b*; lay the Index on the Line *b a*, and turn the Table about till you see the Mark at *a*, and fix there the Instrument.

Then

Then lay the Index to the Point *b*, and turn it about thereon, directing the Sights to the several Angles round the Field as before at *a*, and towards every one of them draw a Line, which will intersect the Lines before drawn at *a*; so shall the Points of Intersection determine the Place of all the Angles round the Field, and Lines drawn from Point to Point shall give the Boundaries of that Field.

But if you be not very exact and curious in drawing the Lines, and also if the Stations are not contrived in such Manner as may prevent the Lines intersecting one another at very acute Angles, you may commit gross Mistakes.

And here it may be observed in this as well as any other Case of the like Nature, that all Things that are to be determined by the Intersection of right Lines, are best determined when those Lines intersect each other nearest right Angles: And therefore when Triangles are laid down from one given Side, and the Length or Position of the other two, and these two make with each other a small Angle, it is difficult to determine the Point where they intersect so exactly as it ought to be.

SECT. V.

Shewing how to measure any Piece of Land by the Chain only.

THOSE who are not provided with other Instruments, may make a Shift to measure a Piece of Land by the Chain only, after the following Manner, though it be somewhat laborious and tedious.

Let

Let Fig. 22. represent a Field, whose Content in Acres is desired without any Plot thereof.

First, Set up Marks (or upright Sticks) at the several Angles A, B, C, D, E, F, G, H, I; and observe as you go along, betwixt which Angles it will be most convenient to run a diagonal or base Line, as the Line A E; so that a Perpendicular from the opposite Angles as B and I, may fall upon this Diagonal or Base in a convenient Manner: And *Note*, it is best to make the *Base* the longest diagonal Line in a Trapezium. or the longest Side of a Triangle; for then the Perpendiculars will be shorter, which in this Method of Surveying is an Advantage.

Having a Sheet of Paper in Readiness, on which to draw an Eye-draught of the whole Work, make some Mark near the Angle at A, and lay the Chain thereto, stretching it in a strait Line towards the opposite Angle E; then draw a strait Line on the Paper to represent the Line A E, which you are about to measure; and proceed with the Chain towards the Angle E.

When you have measured 4 Chains on the Line A E, you will perceive yourself almost over-against the Angle B; therefore having laid the Chain a fifth Time, set down an Arrow at the End of the Chain next E, and let it lie on the Ground in the Direction of A E; then endeavouring to find a Point in the Base A E from which a right Line drawn from the Angle B, may stand at right Angles upon the Base A E.

For this Purpose provide a small Brass Cross, with four plain Sights thereon, having a Socket on the Backside, which put on the Head of a short Staff, and set the Staff in the Ground close to the Chain; then set two of the Sights in the Direction of A E, by looking backwards and forwards through those
Sights

Sights till you can see the Mark in each Angle A and E ; so shall the Mark in the Angle B be seen through the other two Sight, if the Staff be set in a Perpendicular from B ; but if not, move the Staff backwards and forwards by the Side of the Chain, in the Line AE, till through two of the Sight you see A and E, and through the other two the Mark at B ; then will the Staff be set in the Point *a*.

But, if you have not such a Cross, get a Bit of Board made exactly square, in form of a square Trencher, and from Corner to Corner draw strait Lines thereon ; then stick a Pin fast and upright in the Line near every Corner, and make an Hole in the Middle of the Board, so that you may turn it on the Head of a Staff ; this, for once, may supply the Want of the Cross.

Having found the Point *a* in the Line A E, there set down a Staff, and take Notice how many Chains and Links it is distant from A, *viz.* 418 ; therefore apply a Scale to the right Line on your Eye-draught, and near 418 make a Mark at *a* ; but you need not regard whether it be exact or not, so it be within 20 or 30 Links, because the true Lengths of each Line are measured on the Ground.

Then measure on the Ground, in a strait Line, the nearest Distance between *a* and B 600 Links, and erect a Perpendicular on the Point *a* on the Paper, as near as you can guess, by applying the End of a Scale to the Line *a* A ; and by the Edge thereof draw the Line *a* B, setting close thereto 600 Links, the Length of the Perpendicular ; but you need not regard whether the Line *a* B on the Paper be made of its just Length or not ; but only that the Form of the Eye-draught may be something like that of the Field, a Resemblance thereof being all that is requisite in this Case.

Next return to the Arrow, and measure forwards on the Line A E till you are near against the Angle

gle

gle I; and by a few Trials you will find the Point *e* at the Distance of 616 Links from A. Then measure the Perpendicular *e* I, and set the true Length thereof 368, close to its Representative on the Eye-draught,

Now look towards the Fences A B and A I, and because they are strait Lines, draw B A, A I, on the Eye-draught, , so is that Side of the Field finished.

From *e* proceed with the Chain in a strait Line to E, and you will find the whole Length from A to E to be 1375 Links : Then make that right Line on the Paper nearly the Length of 1375, and draw the right Lines E B and E I, cutting the Ends of the Perpendiculars *a* B and *e* I : So shall the greatest Part of the Field be expressed on the Paper, by the Trapezium A B E I.

From E measure in a strait Line towards C, and when you come to *b*, measure the Perpendicular *b* D 60 Links ; then measure out the Line E C to C 800 Links, and draw the Sides E D, D C, on the Eye-draught, to the Extremity of the Perpendicular *b* D. Now number the Angles round the Field, and if you can see the Marks at each, compare them with those on the Eye-draught, and thereby discover what Part of the Field you have already measured, and what remains to be done.

In the same Manner as you measured the Triangle E D C, measure the Triangles E F G and G H I ; then if there be so many Angles expressed on the Eye-draught, as there are Marks at each Angle round the Field, and if the true Length of each Base and Perpendicular, as measured in the Field, be expressed on the Representative of the Eye-draught, you may proceed to cast up the Work.

The same Lines in the Field, *Fig. 22.* are measured on the Land with the Chain, as we should have done

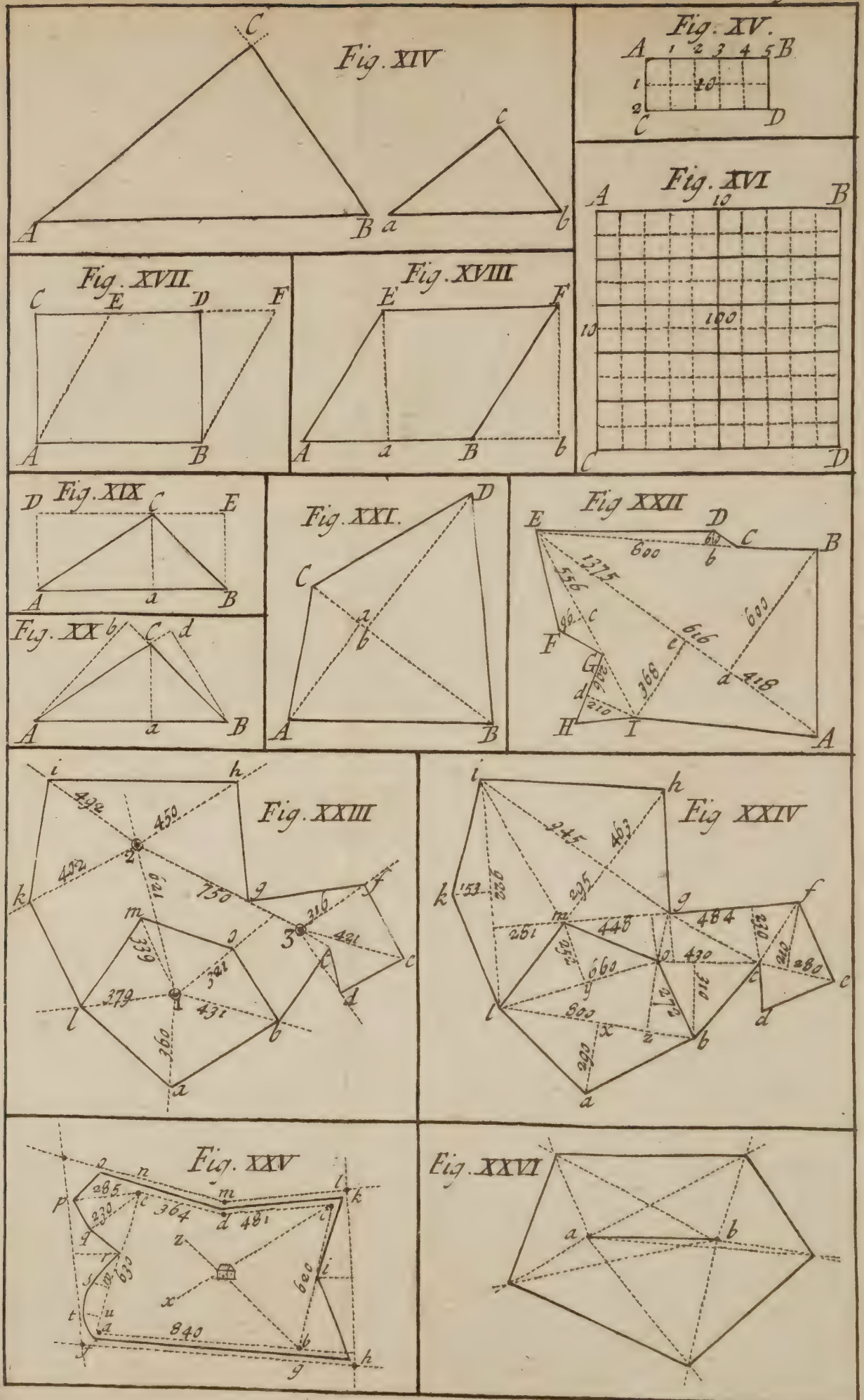
done on the Paper, with the Scale, if the true Plot of the same Field had been first made by the Plain Table or other standing Instrument; and therefore must be cast up in the same Manner, for you have the true Length of each Base and Perpendicular given on the Eye-draught: So the Sum of the two Perpendiculars $a B$, and $e I$, multiplied by the Base $A E$; also the Bases and Perpendiculars of the other three Triangles multiplied together, these four Products added into one Sum, the Half thereof will be the Content of the Field, *Fig. 22*, in square Links, which reduce into Acres, &c. as directed in Sect. 3.

This Method of measuring a Field by the Chain is only proper for plain, level Ground, and small Enclosures: But even then, if the Fences are very irregular, it is better to go round and measure the Angles; taking Off-sets from the Station lines to the Fences.

Indeed if the Fences be tolerably regular (but there are many Fields, whose Sides are not so strait as *Fig. 22*.) you may make a Plot thereof tolerably well, by observing at how many Chains and Links the Perpendiculars join the Base of the Triangles or Trapezias, and erecting Lines on those Points perpendicular to the Base; which being made of their true Lengths, as measured on the Ground, the Sides of the Field may be drawn from the Extremities of the Base to the End of each Perpendicular. Also observe, if any of these Bases be more than 10 Chains, leave a Staff at the tenth, and take the Direction of the Line by that Staff, because the Station will be at too great a Distance; and, if the Length be 20, set up another Staff, and so on.

Or, you may make a Plot of the Field, *Fig. 22*. without measuring the Perpendiculars, after the following Manner; which I take to be a better Method (at least in many Cases) than the preceding.

1. Measure the Sides AB , BE , EI , IA , and the Diagonal AE of the Trapezium $ABEI$, which note on a Piece of Paper ; and note also at how many Chains and Links the Point C in the Line EB falls from E or B , according to which End of the Line EB you began measuring : After the same Manner write down where the Point G falls in the Line EI ; next, measure the Sides ED , DC ; EF , FG ; and GH , HI ; and then the Work that was to be done, and the Field is finished. But because the Angle ADC is very obtuse, and lies but a little Way from the Base CE ; instead of measuring the Sides ED and DC , I would chuse rather to find the Point b , and measure the Length of the Perpendicular bD ; and for the same Reason I would measure the Perpendicular cF ; Also for a like Reason, instead of measuring the Perpendicular $I d$, I would measure the Sides GH and HI , as before directed. For this should be always remembered, that the more Dimensions are taken in the Field, the truer will be the Area of the Plot. Every Surveyor therefore should measure as many Lines and Perpendiculars as possible with his Chain, and not trust more to Angles than is absolutely necessary, as they are very subject to lead him into Error. If you cannot come close to the Fences, you must take Off-sets, as directed in the last Section. The Dimensions of the foresaid Lines being thus taken, you may make a Plot of the said Field after the following Manner. Having drawn a Line cross the Paper, lay thereon the Length of AE taken from a Scale of equal Parts ; then from the same Scale take the Lengths of AB , EB , and therewith form the Triangle ABE (by the Directions in Page 14.) After the same Manner, with the Sides EI , AI , upon the Base AE , make the Triangle AIE ; then will the Trapezium $ABEI$ be completed. Now there remain to be done, only the Triangles EDC , $EF G$,



EFG, and GHI, which may be compleated after the same Manner, or the Triangles EDC and EFG may be made by Help of the Perpendiculars b D and c F, according to which Method you took in measuring them. The Field being thus laid down upon Paper, the Contents of it may be found by Sect. 3. of this Chapter.



C H A P. III.

*Of the Theodolite : And the Use thereof
in surveying a Field, by taking the
Angles which the Fences make with
each other.*



THE Plain Table is very useful for taking the Ground-Plot of Buildings, and measuring Gardens, or small Enclosures, where the Shortness of Lines, and Multiplicity of Angles would be apt to breed Confusion in protracting ; but by no Means fit for surveying large Tracts of Land ; because the least Moisture, or Dampness in the Air, makes the Paper not only sink, but run up when dried again, and thereby the Lines drawn thereon are disordered, making the Content less than it should be ; and, in the least Rain or Mist, the Instrument becomes altogether useless. Also, when the Plot proves larger than will lie on one Sheet of Paper, there must more be pieced thereto with Glue or Paste, which wetting only some Parts of the Paper, is liable to the aforesaid Inconveniencies ; neither can several Sheets of Paper be joined together after the Plot is drawn thereon, so as to meet exactly, and lie so flat as it ought to do. And if to these Inconveniencies be added the Tediousness of compleating the whole Plot in the Field, when a Surveyor has his Assistants

tants about him, we shall have Objections enough to induce any Person to make use of fitter Instruments.

S E C T I.

The Description of the Theodolite.

TH Use of surveying Instruments, by what Name soever they are called, is to measure horizontal Angles ; and for this Purpose the simpler they are made the better, as being easier managed, and less liable to be out of Order : Besides the *Plain Table* (whole Use is properly no more than what may be performed by a Joint-Stool having an Index to turn it upon, though may be not so readily) several Kinds of Instruments have been made for surveying ; as the *Semicircle*, *Perambulator*, and some others with hard Names which I cannot at present recollect ; but all these are contained either in the *Theodolite*, or differ from it only in Name. Also the *Theodolite* itself, notwithstanding the Simplicity of that Instrument in its own Nature, hath undergone various Alterations, which still were called new Improvements : It would be needless to attempt enumerating all these ; it will be sufficient here to describe such an Instrument as may be most simple and fit for Practice.

The *THEODOLITE* is a Circle of Brass divided into Degrees, which are all numbered one Way (and commonly from the Left to the Right, supposing yourself to stand in the Center) to 360° , *vide Fig. 27*. An Angle cannot properly be so great as 180 Deg. But the Limb of the *Theodolite* is numbered to 360, that it may readily express the Arch within the Field that reaches from any two adjacent Sides one to the other ; by which Means the Distinction of

what is called in these Cases external and internal Angles is avoided. As at the Angle *g* *Fig. 28.* the Arch, reaching between the two Sides forming that Angle, contains within the Field 233 Degrees. I have seen some of these Instruments of various Sizes, from 4 Inches Diameter to 20 or 24. But about 9 or 10 Inches Diameter I take to be a good Size. This is big enough for the Purpose of Surveying, and is likewise portable. Upon the Center of the Instrument is a moveable *Index*, having on the Middle a *Compass Box*, with a *Needle* of about 4 or 5 Inches in Length, which is covered with Glass to preserve it from being disturbed by the Air. Within this Box is a Brass Ring divided into Degrees, which are always numbered the contrary Way to the Degrees on the Limb of the Instrument. The Index reaches as far as the Divisions on the Limb, having on the End of it a fine Line to cut the said Divisions; also the End of the Index is usually so divided as to point out on the Limb every *Minute* of a Degree, which is near enough for the Purpose of Surveying. Sometimes there is a Line drawn on the opposite End of the Index, which may serve to examine the Instrument by, and whether the Index turns exactly round the Center. Upon the Index are usually fixed two upright Plain Sights, like those described in *Seet. 2. Chap. 2.* as belonging to the Index of the Plain Table; also underneath the Instrument are fixed two other Sights, exactly like the former, at the Points of 360 and 180. But these last are needless; also, instead of Plain Sights, I think it much better to have a *Telescope* over the Index, having in it a vertical Hair to cut the Object. The Telescope must have some Motion up and down; and it had best turn upon an Axis fixed at right Angles to it. Also in measuring hilly Lands it would be useful to have an Arch with Degrees, shewing the Elevation or Depression of the Index;

But

But this ought to be done in as simple a Manner as possible, without embarrassing the Instrument with unnecessary Work.

The Index ought to move easily and without shaking ; also the whole Instrument should be firm and steady.

The whole Instrument is fixed upon a three-legged Staff, after the same Manner with the Plain Table : Also there is commonly (if not always) annexed to it a Ball and Socket. The Head of the Staff had best be of Brass, because Wood is liable to sink and swell, and by that Means to shake. The Instrument when it is used ought always to be pretty nearly horizontal ; otherwise the Angles measured by it will not be true ; but it is difficult to judge when it lies in this Position, especially when it stands upon uneven Ground. Therefore some Kind of Level ought to be annexed to the Instrument ; a short Plumb-line fixed properly underneath may do very well, for here no great Exactness is required ; or there may be two short Bubbles fixed in the Compass-Box at right Angles to one another ; but then there must be some other Method for adjusting the Instrument, than by opening the Legs. This may be done very well by what the Instrument Makers call a *Rack* ; but the two Plates, with a Ball and Socket between them, fixed to the Head of the Staff, is a better Way. In the upper Plate are four adjusting Screws, bearing upon the lower one, by which the Instrument may be readily brought to its right Position.

The Instrument ought to turn easily upon the Staff, and without shaking, and also there ought to be some Contrivance to fasten it readily in any Position, without twisting it to one Side. The common Way of a Screw turning against the middle Pin is not a good Method, and by the new improved Way (as it is called) of drawing it down upon a Cone, a

small Force will turn it round out of its Place, if great Care be not taken. Instead of these Methods, it may be easily fastened by two crooked small Bars of Brass fixed to the Socket, so as to grasp the Center Pin in four Places or Points. This Method will not be liable either to turn the Instrument to one Side in fastening of it, or of letting it turn round when the said Brass Bars are once skrewed.

The same *Staff* may also serve for a *Plain Table*, a *Spirit-Level*, &c.

If what hath been here said concerning the Theodolite may influence the Instrument-Makers, it may prove of an Advantage to Buyers who are often unacquainted with the Nature of Instruments.

The Manner of taking an Angle with the Theodolite.

Let the Circle *Fig. 27.* represent the Limb of the Theodolite, and let CA, CB, represent two Station Lines in the Field. Having planted the Center of the Theodolite over the angular Point C, being the Index to 360° ; then turn the Instrument about till you see the vertical Hair in the Telescope (or in the Plain Sights, if you use these) cut a Station Staff placed at A; this being done, fasten the Instrument, and turn the Index till it cuts the Staff at B; then the Degrees upon the Limb shew the $\angle DCE$ which is opposite and equal to the $\angle BCA$, to be 70° deg. and so of any other.

The Degrees are numbered in this Manner for the Conveniency of having the End of the Index, which is next the Observer, always point out the Angle. If they were to be read from the Center, the Observer must have gone always to the opposite End of the Index to find his Angle. This last Method is the most natural and intelligible to a Beginner, but the other is most convenient for Practice.

In working with the Theodolite we only measure the Length of the Lines, and Quantity of the Angles in the Field, which we note in a Field-Book for that Purpose ; and by these Directions we may draw the exact Plan of the Land, which is called Protracting.

Provide a Field-Book ruled with three Columns, in the middle Column insert the Quantity of the Angles, and Length of the Station Lines ; in the outer Columns the Off-sets from the Station Lines to the Boundaries, and on each Side note the Remarks which you meet with in the Survey.

S E C T. II.

Shewing the Use of the Theodolite in measuring a Field, by taking the Quantity of the Angles which the Fences or Boundaries make with each other.

THE Theodolite, as before mentioned, is usually numbered on the Limb, from the Left to the Right, and the Box from the Right to the Left ; and therefore the Circuit is most conveniently made (according to the common Phrase) *contra solem*, i. e. with the Fences on the right Hand.

Let *Fig. 28.* represent a Field of which a Plot is desired : First chuse some convenient Place therein to begin the Work, as at $\odot a$ near the Corner of the Field ; and set up a Staff with a Mark thereon, as a Piece of Paper, or a white Rag, so that you may plainly see it at the next Station ; then lay the Chain in a strait Line from *a* towards *b*, having first set up a Staff at *b*.

The Chain lying in this Direction on the Ground, measure with the Off-set Staff from $\odot a$ the Distance
to

to the Hedge 56 Links, and enter in the middle Column of the Field-Book 0, and in the right Hand Column 56, denoting an Off-set laid off from $\odot a$, 56 Links to the right Hand of the Station Line.

Measure forwards on the Station Line $a b$, till you come against the next Bend in the Hedge, then let the Chain lie on the Ground in a right Line between the Stations a and b , and with the Off-set Staff measure the Distance from the Chain to that Bend in the Hedge 140 Links.

Take Notice at what Length of the Station Line each Off-set is laid off; as here at the Length of 540 Links on the Station Line I lay an Onset of 140 Links; therefore in the middle Column of the Field-Book enter 540, and against it in the Column on the right Hand write 140 denoting that at the Length of 5 Chains 40 Links, in the Station Line, you laid an Off-set to the right of 140 Links.

Also take Notice that these Off-sets are to be measured from the Station Line to the Hedge or Boundary in such Manner that the Line representing the Off-set may stand at right Angles with the Chain or Station Line.

Here I would advise a young Beginner not only to enter these Observations in the Field-Book, but also on a Piece of waste Paper to draw first a Line that shall represent the present Station Line, and then upon that to set the Off-sets as he measures them in the Field, drawing the Boundaries as he goes along, not regarding the Length of any Line; a Resemblance of each Line being sufficient, because the true Lengths are entered in the Field-Book: For laying this Sketch before him, when he protracts his Work, he will find it an useful Instruction, in drawing his Angles, and laying the Corners of the Field in their true Position, with other little Difficulties to be met with in Practice; but, when he is

ac-

accustomed to a right Method of keeping the Field-Book, this Trouble may be spared.

Now proceed to measure on the Station Line to the next Bend in the Hedge, and there take an Off-set at 8 Chains 26 Links ; therefore against 826 in the middle Column of the Field-Book write, in the next Column on the Right, 36 Links the Length of the Off-set.

The Hedge continuing strait to $\odot 2$, measure up thereto, and enter the Length in the Field-Book 1120, and measure the Distance to the Hedge 36 Links, which enter in the Column of Off-sets against 1120, and draw a Line cross the Field-Book.

Now remove the Staff from b , and cause it to be set up in a convenient Place, as at c ; then plant the Center of the Theodolite exactly over the Hole, in which the Staff stood at b , (by the Help of a String and Plummets, which you may fasten under the Middle of the Instrument) making the three-legged Staff which supports the Instrument to stand firm on the Ground. Then bring the Index to 360 on the Limb, and turn the whole Instrument about till the Hair in the Sights cuts the Staff at a , and there screw it fast that the Motion of the Index may not cause it to stir from this Position ; then turn the Index about till the Hair in the Telescope cuts the Staff at c , so shall the Index on the Limb shew the Quantity of the Angle abc , viz. 102 Deg. 20 Min. which note in the Field-Book.

Now, that you may be sure you measured this Angle right, turn the Telescope back to the Staff at a , and, if the Hair cuts it, you are right ; otherwise not.

Having measured this Angle, let the Staff be brought from a , and place it in the Hole, over which the Center of the Instrument stood at b ; but leave some Mark at a , that you may find it again when you come round the Field to close the Plot :

Lay

Lay the Chain from b towards c ; and at \odot measure the Off-set to the Hedge 20 Links; at 236 in the Station Line, lay the Off-set 36; at 428 in the Station Line, the Off-set is 92; and at 796 the End of the Line, the Off-set is 30 to the Corner; therefore against 30 in the Column of Off-sets write *Corner*, denoting that the Off-set laid off at right Angles from the Station Line reached the Corner of the Hedge.

Place the Instrument at c , and as before directed, measure the Angle bcd 110 Deg. 40 Min. which note in the Field-Book for the Quantity of the Angle at c .

When you have measured the Angles, and made the necessary Observations at each Station, draw a Line cross the Field-Book, as you will see in the Form thereof; also take Notice, that the Minutes are estimated by the Help of *Nonus's* Invention, which cannot be so well described as by the Sight of the Instrument; only this may be said, that we can thereby estimate the Quantity of an Angle to 1 Minute, which is as exact as they can be laid down on Paper by the Protractor.

Bring the Staff from b , and set it as upright as you can at c ; also send another forwards to d ; then measure on the Line cd , and lay the Off-set to the Corner at 434, against which Off-set write *Corner* in the Field-Book; then measure up to d , entering the Length 468 in the Field-Book.

Plant the Instrument at d , and bring the Index to 360 on the Limb; then turn it about till the Hair in the Telescope cuts the Staff at c , and there fix the Instrument; then direct the Telescope to e , and note the Quantity of the Angle at d , which the Index cuts on the Limb, viz. 230 Deg. 50 Min. which accordingly note in the Field-Book.

In the same Manner proceed with the rest of the Lines and Angles round the Field, till you come to
Station

Station *a* ; but there is no Necessity for measuring the last Angle, or even the last Line, but for the Sake of proving the Truth of the Work, which indeed is convenient.

When the Instrument was planted at *f*, and you had measured the Quantity of that Angle ; the Instrument remaining in the same Position, if you had directed the Telescope to the Tree in the Middle of the Field, and noted the Degrees, &c. which the Index cut on the Limb ; and done the same at *g*, and noted these *Deg.* &c. in the Field-Book, in the Column of Remarks ; you might protract the true Situation of the Tree in respect of any other Part of the Field.

See the Form of these Observations as noted in the Field-Book.

The Field-Book.

Remarks	Off-sets	Station Lines	Off-sets	Remarks
		<i>a</i> ○ 1		
		0	56	
		540	140	
		826	36	
		1120	36	
		<i>b</i> ○ 2		
		21		
		102.20		
		0	20	
		236	36	
		428	92	
		796	30	Corner
		<i>c</i> ○ 3		
		0		
		110.40		
		434	30	Corner
		468		
		<i>d</i> ○ 4		
		0		
		230.51		
		420	30	

The Field-Book continued.

Remarks	Off-sets	Station Lines	Off-sets	Remarks
		<i>e</i> \odot 5 ° ' 5		
	Angle	79.00		
		0	40	
		134	36	
		296	33	
		588	100	
		820	12	
<i>A Tree bears from</i> \odot 6 ° ' 38. 30	Angle	<i>f</i> \odot 6 ° ' 84.30		
		40	120	Corner
		200	24	Corner
		706	16	
<i>Tree bears from</i> \odot 7 ° ' 57. 30	Angle	<i>g</i> \odot 7 ° ' 233		
		380	80	
		648	40	

Scholium.

If the Angle at *a* had been also taken, we might examine whether the Angles were all rightly measured : thus, Multiply 180° by a Number less by two than the Number of the Angles in the Field ; then
if

if this Product be equal to the Sum of all the Angles in the Field added together, it may be concluded that they have been measured right, otherwise there must have been a Mistake somewhere. The Number of Angles in this Field is 7, therefore multiply 180° by 5, the Product will be 900° . The six Angles that are measured make together $840^{\circ} 20'$, and, if no Error hath been committed, the $\angle a$ will measure $59^{\circ} 40'$, which added to $840^{\circ} 20'$ will make the whole Sum 900° . But as there may be Mistakes committed in measuring the Station Lines, (which Mistakes do not come within this Rule) the Surveyor had best depend upon the closing of the last Line with the first Station. If this happens exactly, there is a very great Odds on his Side, that the Field had been measured right : But if the last Line does not so close, if the Error be not in the Protracting (which may happen) the Field must be re-measured till the Mistake be found. And it may be a useful Lesson for a Surveyor to protract each Day as he goes along what he had been doing in the Field. This will prevent his running a great Length in a Mistake, which if he lets alone, may cost him a great deal of Labour to find out.

S E C T III.

The Manner of Protracting the preceding Observations.

AS the Lines are measured in the Field by the Chain, and the Angles by the Limb of the Theodolite ; so the Lines are laid down upon Paper from a Scale of equal Parts, and the Angles by a Protractor.

The *Protractor* should be 7 or 8 Inches in Diameter ; and if it be a whole Circle, which is best for
Beginners,

Beginners, it should be numbered into 360 *Deg.* the same Way with the Limb of the Theodolite; only with this Difference, that the Numbers upon the Protractor should stand so as to be read from the Center. Sometimes in the middle Bar is a Slit about an Inch long, having one Edge a little sloping; this Edge is divided into 12 Parts, each of which stands for 5 *Min.* The Point denoting 0 *Min.* is in the Diameter passing through 0 or 360 *Deg.* and 180 *Deg.* A Line passing from the Center through the Point denoting 60 *Min.* upon the said Edge makes an \angle with the Diameter of 1 *Deg.* so that if the Center of the Protractor be put to a Point in a given Line, and the Instrument be turned about its Center, until 5', 10', 15', 20', 30, or 40', &c. cut the said Line, the Diameter of the Protractor will accordingly form therewith the Angles 5', 10', 15', 20, or 30', &c. respectively; then the whole Degrees may be pricked off by the Limb. Thus, if I was to make an \angle of 52° 35' : Having put the Center of the Protractor to the angular Point, I turn the Protractor about till 35 *Min.* cuts the given Line, then I will make a Prick or Point in the Paper exactly against 52 *Deg.* a Line drawn through this Point will form, with the given Line, the \angle required. These Instruments, I think, are called by the Makers *Diagonal Protractors*; but I believe they are seldom used by practical Surveyors, because the Operation by them is somewhat tedious.

Instead of the common Scales, you may have one divided all the Way at the Edge, like that in the Frontispiece. This is useful and expeditious, especially for finding the Points in the Station Lines where the Off-sets come. If your Protractor is a Semi-circle, you may have such a Scale cut on the outward Edge of the diametrical Bar.

Provide a Skin of Parchment, if the Plot is desired to be on Parchment, according to the Large-

ness of the Work you are about to lay down ; or if on Paper, let it be large enough to hold all your Work ; the strong Cartridge Paper for this Purpose is accounted best by some Surveyors.

Having considered which Way the Plot will extend, draw an obscure Line on the Paper to represent the first Station Line, and mark the End thereof with $\odot a$ (*Fig. 28.*) so shall that Point represent the first Station in the Field : Lay the Edge of your Plotting-Scale close to this obscure Line, the Beginning of the Numbers coinciding with $\odot a$, and encreasing towards the next Station ; then lay the Field Book open before you, and because the Off-sets in the first Length are taken at the Distances 0, 540, 826, 1120 ; therefore against these Numbers on the Scale, make Marks in the obscure Line, close to the Edge of the Scale.

This done, turn the Scale perpendicular to the obscure Line, so that the several Off-sets may stand thereon at right Angles as aforesaid ; and apply it successively to these several Points, and there prick off the Length of the several Off-sets on the same Side of the obscure Line as noted in the Field-Book ; so at \odot prick off 56 ; at 540, the next Length, prick off 140 ; at the next Point, which is at the Length 826, prick off 36 ; and at 1120, the End of the Line, prick off 36 ; or these Off-sets may be taken with the Compasses from a common Scale.

Now if Lines are drawn from Point to Point, they shall represent the Boundaries of this Side of the Field ; and because the Hedges, especially in old Inclosures, are generally in the Form of a Curve rather than strait Lines ; therefore if you draw the Boundaries from Point to Point with a Quill Pen with your Hand only, they will be more naturally expressed, than if you lay a strait Ruler from Point to Point, (except the Distances are very long, or you take a Multitude of Off-sets ;) and to be exact,

'tis

'tis sometimes necessary to express the Nature of these little Irregularities in the Fences, by a Sketch on one Side of the Field-Book.

The Length of the first Station Line being 1120, mark that Distance from $\odot a$, with $\odot b$; and let the obscure Line be produced each Way as long as the Radius of the Protractor.

Lay the Center of the Protractor to the Point $\odot b$, and turn it about thereon, till the Diameter lies on the Line ab , the Beginning of the Numbers on the Protractor being laid towards $\odot a$, contrary to the Theodolite in the Field.

Hold the Protractor close down to the Paper in this Position, and because the Angle at b is 102 Deg. 20 Min. therefore with a protracting Pin or Needle, make a Mark against 102 Deg. 20 Min. close to the Limb of the Protractor, through which Mark from b , draw the obscure Line bc .

So is the Station Line bc , laid down in the same Direction as in the Field, and the Angle abc , the same.

Lay the Plotting-Scale to the obscure Line bc , the Beginning of the Numbers coinciding with the present Station, and the Numbers encreasing towards the next; then close to the Edge thereof, against 0, 236, 428, 796, the Lengths where the Off-sets were taken, make Marks with the protracting Pin; and turn the Scale perpendicular to the obscure Line, and prick off the several Off-sets, 20, 36, 92, 30.

And now if Lines are continued from the Fences before drawn to these Off-sets, they shall represent the Boundaries on this Side of the Field.

The Off-set at the End of the second Station Line, at c , reaches into the Corner; but those at b must be continued till they meet one another, and this might be expressed in the Field-Book or Sketch, that you may not mistake the Corner of the Field.

Lay the Center of the Protractor to c , the Diameter being held close to the Line bc , and against $110\text{ Deg. }40\text{ Min.}$ on the Limb of the Protractor, make a Mark, through which draw the Line cd .

At the Length 434, in this Line lay the Off-set 30 Links, to which continue the Boundaries before drawn; so is this Side of the Field finished.

Note, The next \angle at d being $230^\circ 50'$, subtract this Number from 360, and note the Remainder $229^\circ 10'$; then turn the Protractor the contrary Way, *viz.* so that the Arch may be to the outside of the Field; and counting from c , make a Point at $229^\circ 10'$, through which Point draw the Line de .

Or if the Protractor be numbered to 360, on a Circle concentric to the outward Circle, and the Numbers on both encrease the same Way, (as the Limb of the Theodolite) then, the Protractor being turned reversely as above, the Angle $230\text{ Deg. }50\text{ Min.}$ may be pricked off from the inner Circle.

But if you use a circular Protractor, it may be laid always one Way, *viz.* the Beginning of the Numbers towards the last Station, contrary to the Theodolite in the Field; and this in my Opinion is the best Way.

But if you use a semicircular Protractor, observe to lay the Diameter on that Line which brought you to the present Station; and to lay the Beginning of the Degrees of the Protractor towards the last Station when the Angle is less than 180 Degrees; but the contrary Way when the Angle is more.

So at d lay the Diameter of the Protractor on the Line cd , the Beginning of the Numbers being laid the contrary Way to c ; and against $230\text{ Deg. }50\text{ Min.}$ on the inner Circle of the Protractor, make a Mark, through which draw the Line de .

In the same Manner lay down the Angle at e , and draw the Line ef , continuing the Boundaries as before directed.

When

When you have marked the Angle at *f*, let the Protractor lie in the same Position, and make a Mark against 38 Deg. 30 Min. as noted in the Field-Book for the Bearing of the Tree from that Station, and through that Mark draw an obscure Line from *f*.

Do the same at *g*, continuing the obscure Line from thence till it crosses that drawn from *f*, so shall the Intersection of these two Lines determine the Situation of the Tree in the Middle of the Field.

In the same Manner may any other inaccessible Distance be measured by the Theodolite.

When you have marked the Angle at *g*, and drawn the Line *g a*, it will cut through the Point *a*, and the Length of the Line *g a* will be the same as that noted in the Field-Book, which proves the Plot to be truly laid down. But if the last Line had not passed through *a*, or was not of the same Length on the Paper as that noted in the Field-Book, some Error must have been committed in the Field, or in Protracting.

S E C T. IV.

How to measure Angles by the Chain.

FOR this Purpose provide three round Station-Staffs four or five Feet long a-piece; and also take Care that the Ring in the Middle of the Chain, and also those at each tenth Link, be at their due Distance from the Chain's End

1. In order to measure the Angle *d o e*, *Fig. 29.* set one of your Station-Staffs as upright as you can at *o*; and putting the Ring at one End of the Chain over it, let one of your Assistants take the other End

in his Hand, and stretch out the Chain towards d ; whilst you standing at o , direct him to move sideways till the Station-Staff which he has in his Hand, be brought into one right Line with o , d , as at a , and there let him leave the Staff.

Then let him with the End of the Chain in his Hand, move towards e ; and, as before, direct him to plant the third Staff upright in the Line oe , at b .

Measure the Distance ab in Links and tenth Parts, if less than one Chain, and enter them in the Field-Book $88\frac{1}{2}$.

When you plot this Angle, take with a Pair of Compasses from a large Scale, the Distance of one Chain; and having drawn a Right Line do , set one Foot of the Compasses in o , and with the other describe an Arch ac ; then from the same Scale take $88\frac{1}{2}$ Links; and setting one Foot of the Compasses at a , let the other fall in the Arch ac , and make a Mark at b : Lastly, through this Mark, from o draw the Line oe , constituting the Angle doe .

Observe to plot your Angles by a large Scale, as an Inch, or two Inches, and the Length of the Sides by a smaller, as a Quarter or half an Inch: Also observe, that when the Length of the Chord ab is longer than one Chain, then it is best to lay out a Sextant, or two Sextants, in the following Manner.

The Manner of measuring Angles with the Chain, by laying off Sextants, is deduced from this known Property of the Circle; *viz.* *The Radius of every Circle is equal to the Chord of one sixth Part (or a Sextant) of its Periphery.*

2. Let it be required to measure the Angle bac , Fig. 30: First, set up a Staff at a , and lay the Chain strait in the Direction of ab to i , and at 50 Links set down an Arrow at o ; then let your Assistants hold the Ends of the Chain at o , and a , whilst

whilst you with the Middle in your Hand, stretching both Halves strait, set down an Arrow at *e*, constituting the equilateral Triangle *o a e*; so have you laid out the Angle *o a e*, a Sextant.

But if you have two Chains, you may (which is better) lay out the Sextants, so that each Side of the equilateral Triangle be one Chain.

Now the Chain's End being still held at *a*, stretch it through the Point *e* to *d*, where also set down an Arrow: Lastly, measure the Distance from the Arrow at *d*, to a Staff set up one Chain's Length from *a* at *u*; so shall the Distance *d u* be 76 Links, and four Tenths of a Link; therefore enter in the Field-Book 1°. 764^p. implying 1 Sextant and 764 Parts.

In order to plot this Angle *b a c* thus measured, chuse some Line divided into 1000 Parts, and making this Line Radius, set one Foot of the Compasses in *a*, and with the other describe the Arch *iz*; the Compasses continuing at the same Extent, set one Foot in *i*, and with the other cross the Arch at *d*, and there make a Mark.

Then take 764 Parts from the same Line, divided into 1000 Parts, which you make Radius; and setting one Foot of the Compasses in the Mark at *d*, let the other cross the Arch at *u*, and there make a Mark: Lastly, from *a*, draw a Line thro' the Mark at *u*, and you will construct the Angle required.

If you have not a Line (which is best) actually divided into 1000 Parts, use the largest diagonal Scale you have; so you may take off 76 Parts exactly; and the four Tenths you must guess at by moving the Compasses near half Way in the Diagonal towards 77; also observe, the 10th of a Link is measured on the Land by the Off-set Staff, having a Link or two thereon, divided into ten Parts.

3. If the Angle be more than two Sextants, as in *Fig. 31*; then having, as before, laid off the Sextant $e o a$, let your Assistants hold the Ends of the Chain at a and e , while you with the Middle in your Hand, set down an Arrow at x , constituting another Sextant $e a x$.

Then the Chain being held at a , lay it through x , and at the other End d set down an Arrow; Lastly, measure $d u$, which suppose to be 42 Links and 5 Tenths; therefore enter in the Field-Book $2^s, 425^p$, signifying 2 Sextants and 425 Parts.

If you would protract the Angle of *Fig. 31*; with the Length of the Line divided into 1000 Parts, describe the Arch iy , and thereon lay $i n, n d$, each equal to the Radius or divided Line; and afterwards lay 425 equal Parts from d to u , and draw $a u$; which gives the Angle required.

Observe, if you were about to measure the Angle, *Fig. 31*. and had set up one of your three Staffs where the Station-Lines meet in the angular Point a , another at i , and the other at u , in the Lines $a b, a c$; before you proceed to measure the Angle $i a u$, you must be sure that the Staffs at a, i , and b are exactly in the same strait Line; and also the Staffs at a, u , and the Mark at c , in another strait Line.

So when the Staff at a is planted as nearly perpendicular as you can, move yourself backwards; the farther the better, till you see the Staff at a , and that at i , in one strait Line with the Mark at b ; there stand, and direct your Assistant to place his Staff, so that the Staff at a exactly cover that at i , from the Top to the Bottom.

Note, You must take Care that the Staffs are upright, so as to lie in the same Plane.

4. If an Angle be external, and so contain more than three Sextants, as $b a e$, *Fig. 32*. put the Ring at one End of the Chain over the Staff at a , and taking the

the other End in your Hand, stretch out the Chain at length towards d , and move sideways, till you perceive yourself in a Right-Line with a b , and there at the End of the Chain set down an Arrow at d , so that d , a , b are in the same right Line; then set down the other Staff at c , at the End of one Chain also; so that the Staffs at a and c be in the same Plane with the Mark at e . Now measure the Angle $d a c$, in the same Manner as aforesaid, and to it add the Sextants, so will the Sum be the Measure of the external Angle $d a c$.

So if the Angle $d a c$, be 947, then will the external Angle $b a c$, be 3 Sextants, 947 Parts; and if the Angle $d a c$, be 1° . 947, then $b a c$ will be 4° . 947, &c.

When you protract the external Angle $b a e$, first continue the Line $b a$; then from the Angle subtract 3 Sextants, and make the Angle $d a e$, equal to the Remainder.

But if you go on the Outside of a Field or Wood, you may then work as though you were within the Wood, by measuring the Angle vertically opposite to those that are internal: So in *Fig. 33.* if you measure the Angle $o a u$, instead of $b a e$, it will do your Business when you come to protract, as well as if you had measured $b a e$ on the Inside; for, if two Right-Lines cross one another, the contrary or vertical Angles are equal. *Euclid*, 15. 1.

Angles measured by the Chain, may be laid down by a Protractor made on Purpose, having Sextants and Links divided thereon; and then to be used in the same Manner as other Protractors.

The Manner of keeping the Field-Book, is in all Respects the same as that used in the 2d *Set.* of this *Chap.* except that when the Angles are measured by the Theodolite, you note the Quantity of each by Degrees and Minutes: In this Case, when measured by the Chain, you note the Quantity by Sextants and Parts.

So

So if you were to measure the Field, *Fig. 28.* by the Chain; instead of noting $102^{\circ} 20'$, for the Quantity of the Angle *b*, you must note 1 Sextant 734 Parts; and instead of $230^{\circ} 50'$, for the external Angle *d*, you must note 3 Sextants, 886 Parts; but the Station Lines, Off-sets, &c. will still be the same.

There are other Ways of working with the Chain; but these before mentioned are the best and exactest, and contain as much Variety as any one will commonly put in Practice: You may also thereby measure an inaccessible Distance, and do several other Things; but these are only for a Shift, when we have no other Instruments: And the same may be said of measuring Angles.

S E C T V.

Of the Circumferentor.

THE *Circumferentor* is only a Compass-Box and Needle, having two plain Sights perpendicular in the meridian Line of the Box; or, instead of the plain Sights, a Telescope may be mounted over the Box, so that it may be elevated or depressed to an Object as there shall be Occasion. This Instrument is supported by a three-legged Staff, like the Theodolite and the Plain Table. If the Index of the Theodolite be taken off, and fitted to a three-legged Staff, it will then be a perfect Circumferentor: So that he who hath the former of these Instruments, hath the other also contained in it.

In surveying Harbours, Sea-coasts, Counties or large Commons, where the Lines are very long; or thick overgrown Woods, where we may be forced to make a Multitude of Angles, and the Sight of the two Lines constructing the Angle, may be hindered

hindred by the Brush or Underwood ; in these and such Cases, where no great Exactness is required, the Angles may be measured by the Needle only ; and this Method, it must be owned, is very expeditious, because the Trouble of observing the back Stations is saved. Yet in surveying Lordships, Inclosures, or plain Pasture Land, (a small Piece of which got or lost is of a considerable Value, and each particular Field ought to close exactly) the Angles are, without doubt, more surely measured by the Limb of the Theodolite ; because the Degrees in the Box cannot be so nearly estimated, and the Needle is liable to be drawn aside by some hidden magnetic Power.

The Position or Bearing of a Line observed by the Needle is expressed by such a Number of Degrees and Minutes as it is distant from, or Quantity of the Angle, which that Line makes with the Meridian.

If a Person wholly unacquainted with the Use of this Instrument, will take the Pains to try this following Method, it may be an Help to conceive the Manner of using it in the Field.

Upon a Sheet of Paper let there be drawn right Lines parallel one to another at any Distance, and upon a Table let there be fixed a Pin with a Point upwards ; let the Pin so fixed be run through one of the Lines on the Paper ; upon the Point of the Pin, let there be put a magnetic Needle, and let it traverse about till it rests of itself ; then turn the Paper about on the Table till the Needle hangs directly over the Line, in which the Pin is placed, which is discovered by fixing the Eye over its Center ; then with sealing Wax fasten the Paper to the Table by the four Corners ; so may the Paper be supposed to represent the Surface of the Earth, and the Lines the magnetic Meridian, (which mark at the Top with North, and at the Bottom with South.)

If the Pin be removed into any other of the Lines, and the Needle be made to traverse thereon, it will, when at rest, hang directly over the Line in which the Pin is placed, if the said Line be drawn parallel to the first Line, over which the Needle hung when the Paper was fixed.

The Needle then points always to, or lies in the Direction of the Meridian, by virtue of the magnetic Power; so if I had fastened to the Table a Sheet of blank Paper, and had laid a Ruler in the same Direction with the Needle when at rest, and had drawn a meridian Line, and then removed the Needle to another Part of the blank Paper, and drawn another such a Line by the Direction of the Needle, that Line would have been parallel to the former.

When we take an Angle in the Field by the Needle, the meridian Line is always one Side of the Angle; and the Hedge, Wall or Fence along which the Telescope is directed, is the other Side of the Angle, and they are supposed to meet at the Center of the Instrument.

Set one Foot of a Pair of Compasses in some one of the Meridians on the Paper, and describe a Circle, then the said meridian Line is its Diameter: Divide this Circle into 360 Degrees, which is easily done by the Protractor, and let the Numbers begin at N. or North, and encrease to the left, towards E. or East.

Then this Circle represents the Box of the Instrument in the Field, and the Line N. S. represents the Needle.

From the Center of the Circle, draw a long Line any Way at Pleasure, and let this Line represent an Hedge or Station-Line in the Field; and to find its Bearing or Angle that it makes with the Meridian, look what Degree, &c. it cuts on the Circle; and that will be the Quantity of the Angle or Bearing from the Meridian.

So the Needle used in the Field points out the magnetic Meridian, and the Divisions in the Box moved under it measure the Angle, that any Line in the Field makes with that Meridian.

The Box of the Circumferentor is commonly numbered from the right to the left ; the Numbers beginning at N. or North, which is marked also with a Flower-de-luce, encreasing towards E. or East ; and the Direction is to be taken from the North End of the Needle.

The Use of the Circumferentor in Surveying Land.

Let it be required to observe the Bearing of the several Station-Lines which incompass the Wood,
Fig. 34.

First plant the Circumferentor at some convenient Station, as at *a* ; the Flower-de-luce in the Box being from you, direct the Sights to a Mark at the next Station *b*, and note the Division which the North End of the Needle points to in the Box when at rest, which is 260 Deg. 30 Min. therefore note this Number 260 Deg. 30 Min. in the Field-Book, for the Bearing of the Line *a b*.

Observing former Directions for removing the Theodolite from one Station to another, and measuring the Station-Lines and Off-sets from thence to the Boundaries as you pass along the Station-Lines, let the Instrument be removed from *a*, and planted at *b*, the next Station ; then keeping the Flower-de-luce in the Box from you, turn the Instrument about till the Hair in the Sights cuts a Mark at the next Station *c* ; then will the North End of the Needle point to 292 Deg. 12 Min. which note in the Field-Book for the Bearing of the Line *b c*.

The Instrument being planted at *c*, and the Sights directed to *d*, the Bearing of that Line *c d* will be 331 Deg. 45 Min.

In

In the same Manner proceed to take the Bearing of other Lines round the Wood, observing this general Rule, *viz. Keep the Flower-de-luce in the Box from you, and take the Bearing of each Line from the North End of the Needle.*

The Numbers in the Card of some of these Circumferentors are made to encrease towards the right, but that before-mentioned is best ; for when you turn your Instrument to the Eastward, the Needle will hang over the Westward Division on the contrary Side.

Instead of planting the Circumferentor at every Station in the Field, the Bearings of the several Lines may be taken if it be planted only at every other Station.

So if the Instrument had been planted at *b*, and the Flower-de-luce in the Box kept towards you when you look back to the Station *a*, and from you when you look forwards to the Station *c*, the Bearings of the Lines *a b*, and *b c*, would be the same as before observed : Also the Bearings of the Lines *c d*, and *d e*, might be observed at *d* ; and *e f*, and *f a*, at *f* ; so that instead of planting the Instrument 6 Times, you need in this Case plant it but 3 Times, which saves some Labour.

But since you must go along every Station-Line, to measure it or see it measured, the Trouble of setting down the Instrument is not very great, and then also you may examine the Bearing of each Line as you go along ; and if you suspect an Error in the Work by the Needle's being acted upon by some hidden magnetic Power, or from your own Mistake, in observing the Degrees that the Needle points to, you may correct such Error at the next Station before you proceed.

As when the Instrument was planted at *a*, and the Sights directed to *b*, the Flower-de-luce from
you,

You, the North End of the Needle pointed to 260 Deg. 30 Min. now being come to *b*, direct the Sight back to a Mark at *a*, keeping the Flower-de-luce towards you : So shall the North End of the Needle point to 260 Deg. 30 Min. as before at *a*, and then you may be sure the Bearing of the Line *ab* is truly observed.

But if the Needle doth not point to the same Number of Degrees, &c. there hath been some Error in that Observation, which must be corrected before you proceed.

If you have a Suspicion that the Needle doth not play well, when the Instrument is planted at any Station, as at *a*, direct the Sights to the Mark at *b*, and note the Degrees, &c. pointed at by the Needle in a Piece of waste Paper ; then with a clean Knife, Key, or any Bit of polished Steel, move the Needle by applying it to the Box, and examine when it hath settled again what Degrees it then points at, the Sights being still directed to the preceding Mark at *b* ; and if the Degrees are the same, they may be entered in the Field-Book ; but if not, the Cap and Pin must be cleansed with some brown Paper and a little Putty, and thereby freed from such Dust or Dampness that hath gotten to it. If after all the Needle does not play freely, place in the Box another Pin, or use another Needle, or do both, and these Necessaries a Surveyor ought to have in his Pocket while he is in the Field.

If you would measure the Quantity of any Angle by the Needle, place the Instrument at the angular Point, and take the Bearing of the two Lines constructing that Angle, and subtracting the lesser out of the greater, the Remainder is the Quantity of that Angle, if less than 180 Degrees ; but if the Remainder is greater than 180 Degrees, subtract it out of 360 Degrees, and that last Remainder is the Angle.

The Manner of entering the Off-sets in the Field-Book is before shewn in the Use of the Theodolite; it will be sufficient, in this Place, to insert the Bearing of each Line or Quantity of the Angle which each makes with the Meridian, together with their Lengths, in order to protract or lay them down on the Paper Plot of the same Length, and in the same Direction as in the Field. *Vide Fig. 34.*

As this Instrument is so very subject to Error, the Practitioner should never use it, except Necessity oblige him to it; for, as an Angle can hardly be taken by it to a Degree, the Errors will be remarkably large, if the Lines are of any Length.

S E C T. VI.

The Manner of Protracting the aforesaid Observations made by the Circumferentor:

Links	Bearings	Lines	
<i>a b</i>	260°	30' ———	1242
<i>b c</i>	292	12 ———	1012
<i>c d</i>	331	45 ———	1050
<i>d e</i>	59	00 ———	1428
<i>e f</i>	112	15 ———	645
<i>f a</i>	151	30 ———	1806

First, Draw Lines parallel to one another quite through the designed Draft, at Distances not exceeding the Breadth of the Diameter of your Protractor; as in *Fig. 34*, and mark them with N. and S. for North and South; then considering which Way the Plot will extend, assign a Point in some one of the parallel Lines, to represent the first Station in the Field, as at *a*; to which Point lay the Center of the Protractor, and by the Help of the Divisions continued beyond the Ends of the Diameter of the Protractor

tractor, lay the Diameter upon, or parallel to those North and South Lines; the Beginning of the Numbers on the Protractor towards that Part of the Line marked with N. or Northwards, when the Degrees are fewer than 180, but Southwards when more: The Protractor being thus placed, look in the Field-Book for the Bearing of the first Line *ab*, which is 260 Deg. 30 Min. therefore with the Beginning of the Numbers on the Protractor towards *s*, close to the Limb against 260 Deg. 30 Min. make a Mark; and through that Mark from an assigned Point at *a*, draw a Line *ab*, on which Line set 12 Chains 42 Links, as noted in the Field Book.

So will the Line *ab*, on the Paper, have a Bearing like to that which you observed the Line *ab* to have in the Field, in respect to the Meridian: But the Protractor, to lay down these Observations, must be numbered contrary to the Box of the Circumferentor; and if it be a Semicircle it must be numbered, first to 180, and then on the inner Circle, whose Numbers must increase the same Way as the outer Circle to 360; the Bearings greater than 180 are pricked off from this inner Circle, and the Beginning of the Numbers must be laid Northward or Southward as the Degrees of Bearing are less or more than 180. If your Protractor be a whole Circle, the Beginning of the Numbers may be kept always one Way, as the Numbers of the Circumferentors were in the Field; but the Diameter must be always laid upon a Parallel to the Meridian Lines, and may be marked with N. S. at the Ends as a Direction to keep it in its true Position.

Having made the Line *ab* of its true Length and Position, the next Thing to be done is to lay the Offsets therefrom, which gives the Boundary of that Side of the Wood, *Fig. 34.*

Lay the Center of the Protractor to the Point *b*, and because the Bearing of the Line *bc* is more than

G

180;

180; lay the Beginning of the Numbers of the Semi-circular Protractor towards S; and against 292 Deg. 12 Min. make a Mark, through which Mark from *b*, draw the Line *b c*, setting the Offsets therefrom, and draw the Boundary of that Side of the Wood.

In the same Manner lay down the other Lines *c d*, *d e*, *e f*, and *f a*; so will the Line *f a* cut thro' the Point *a*, and be of the same Length on the Plot as that measured in the Field, if the Observations be truly made.

Then if you drew the Station-Lines, and Offsets, with a black-lead Pencil, and the Boundaries with Ink, you may with a Piece of Bread rub off those Lines, so shall the Boundaries of the Wood only remain, which gives the exact Figure thereof.

S E C T. VII.

The Manner of casting up the small irregular Pieces of Ground, which lie between the Station-Lines and Hedges.

IT very rarely happens that the Sides of a Field are all strait Lines, and therefore any Method for measuring them from one or more Stations in the Middle, can seldom be put in Practice; the best Way being to go round, and measure the several Angles from Stations near the Boundaries, but at such a Distance from thence that we may see clearly from one Station to another, and have plain Ground to measure the Distances free from the Incumbrance of Brushwood, Trees, &c. So shall the greatest Quantity of the Land be included between the regular Station-Lines, which is cast up as before directed, by dividing the same into the largest Trapezias and Triangles possible; and measuring the Bases and

Fig. 29

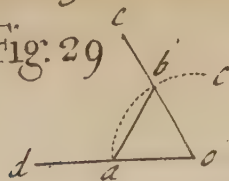


Fig. 30

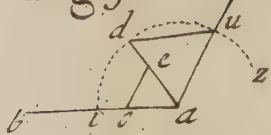


Fig. 31.

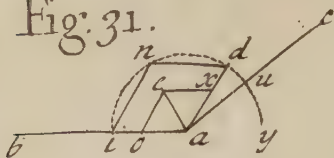


Fig. 32

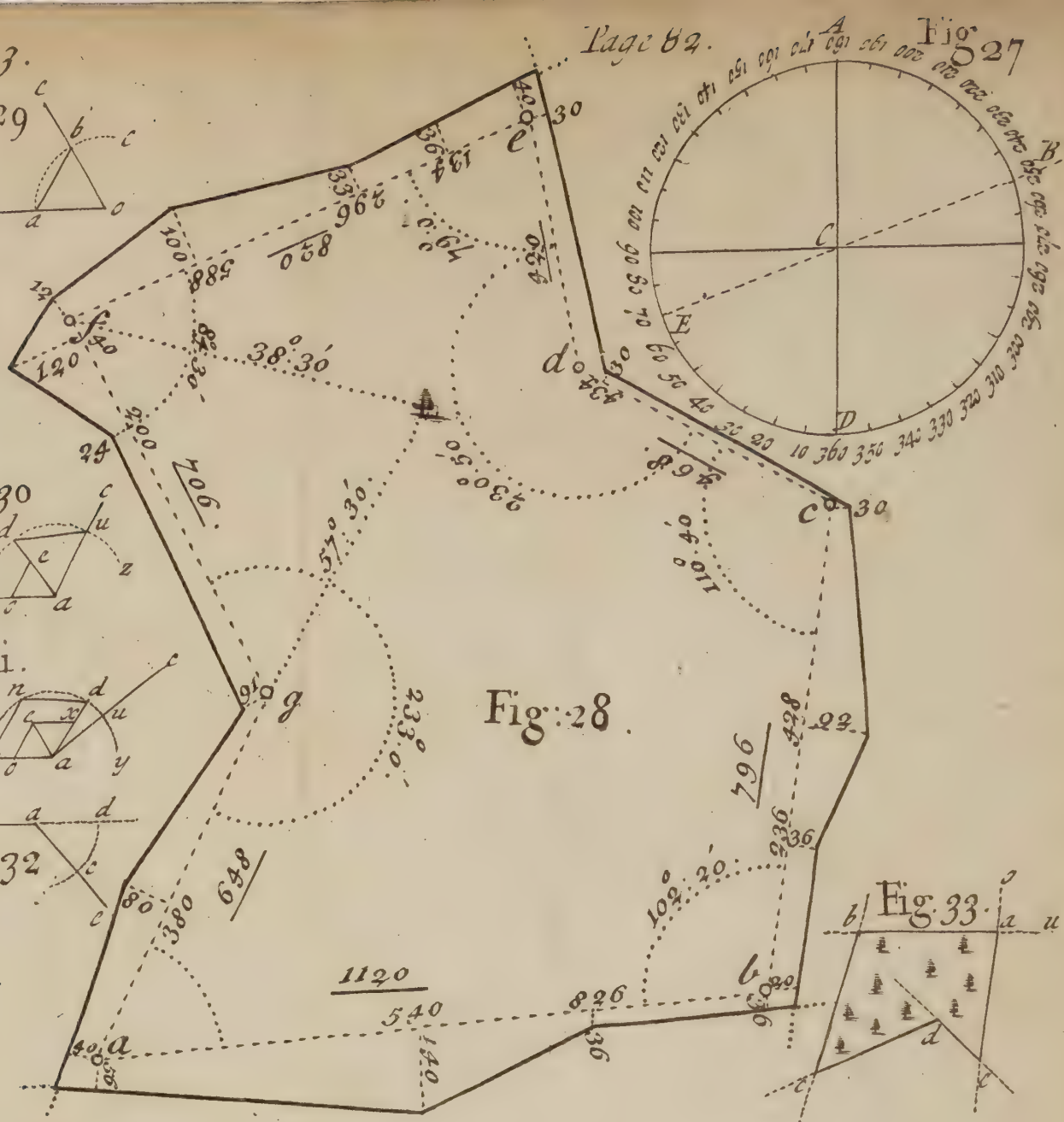
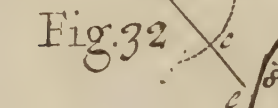


Fig: 28

Fig. 33

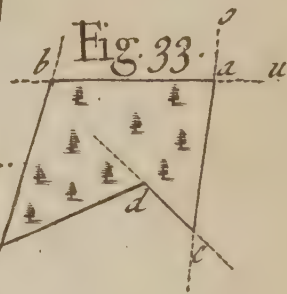


Fig 34

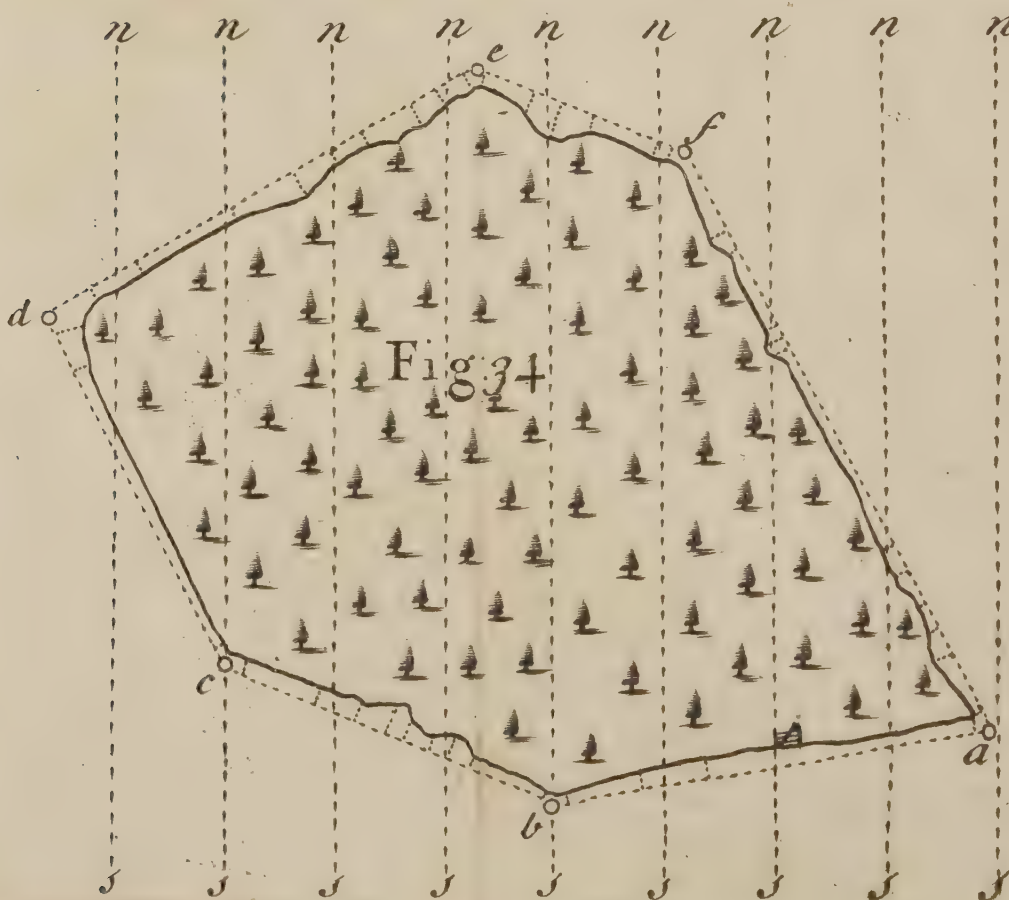
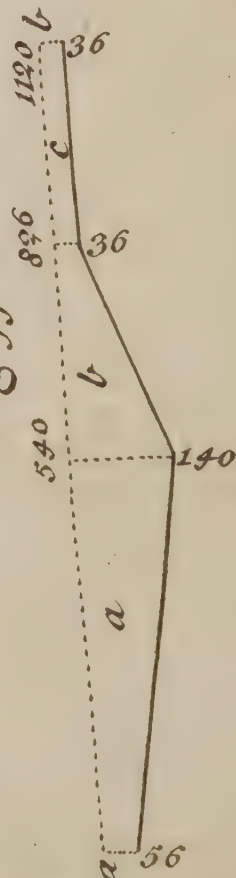
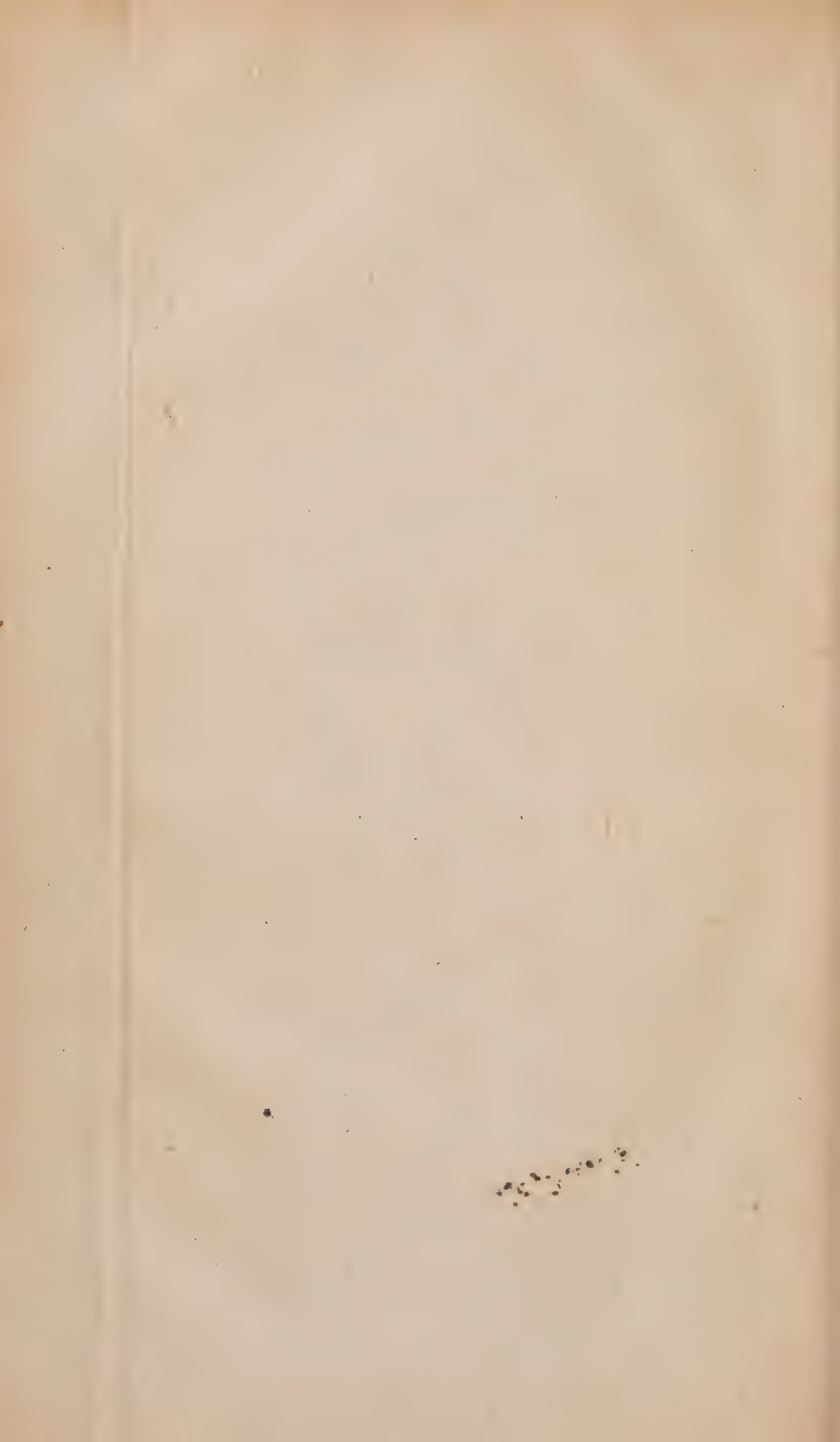


Fig: 35





and Perpendiculars by the same Scale that the Plot was laid down by.

But in order to cast up the small irregular Pieces comprehended between the Station-Lines and Boundaries ; if you reduce them into Triangles, &c. as they will be a great many in Number, so you may commit very considerable Errors in laying of them down first, and taking them off afterwards, especially if the Scale you protract by be very small. For the Removal of this Inconvenience, I shall here shew a Way whereby you may cast up these small Quantities, however small the Scale may be, as exactly as any of the greater Parts of the Field.

Suppose the small irregular Pieces between the Station-Lines and Boundaries, *Fig. 28.* were to be cast up.

First lay the Field-Book before you, where you will find the Length of the first Off-set (as measured in the Field with your Off-set Staff) from \odot 1 at *a*, to be 56 Links, and the second at 540 in the Chain-Line, 140, forming the small Trapezium *a*. *Vide Fig. 35.*

Now, if you add the Off-set 56 to the next 140, the Sum will be 196, the Half of which is 98, the equated Breadth ; multiply the Length 540 by 98, the Product is 52920, the Content of the Trapezium *a*, in square Links.

Add 140 to 36, the Sum is 176, the half Sum 88 ; subtract 540 from 826, the Remainder is 286, the Length of the Trapezium *b* ; therefore multiply 286 by 88, the Product is 25168, the Content of the small Trapezium *b*.

Subtract 826 from 1120, the Remainder is 294, the Length of *c* ; and because both the Off-sets are alike, multiply 294 by 36, the Length of the perpendicular Off-set, the Product is 10584, the Content of the small Piece *c*.

In the same Manner deal with the rest of these small Pieces round the Field, and set down the Product of each in an orderly Manner one under another ; so shall the Sum give the exact Content of these small Pieces, which, added to that within the Station-Lines, gives the true Content of the Field in square Links, which reduce into Acres, &c. as before directed.

Note, The Performance of this being tedious, in the next Chapter will be laid down a more expeditious Method for casting up the Content of any Piece of Land.



C H A P. IV.

Shewing the Use of the Theodolite in Surveying Land, by the Help of the Needle and Limb together.

S E C T. I.



IN this Method of Surveying Land, the Angle which every Line makes with the Meridian is measured by the Limb of the Theodolite, and therefore much preferable to that before-mentioned in the preceding Chapter by the Needle only; because the Degrees and Minutes are better estimated on the Limb of the Instrument than 'tis possible they should be in the Box of the Circumferentor; and this gives the Theodolite the Preference to any other Instrument, because we can work by the Limb only, without regarding the Needle at all: but if it be more convenient to make use of the Needle, we may do it in the following Manner, being the usual Method for surveying large and spacious Tracts of Land.

The Needle being observed to play well, when it hath settled in the Direction of the Meridian and is at rest, the Box may be moved round the fixed Center by turning the Index on the Limb and the Point marked with 360 in the Box, brought directly against the North End of the Needle, with greater Exactness than a Degree, and its Parts can be esti-

mated in any other Part of the Box ; besides, we have this Advantage, which is very considerable, that we can make Use of a short light Needle, whose Friction being less, plays better than a longer and heavier.

Let the Lines $\odot a$, bc , de , ef , in *Fig. 36.* represent the Station-Lines near the Boundaries of a Field ; then the Angle which each makes with the Meridian, may be observed in the following Manner.

First, having set up a Mark at \odot , measure forwards with the Chain on the Line $\odot a$ to a 600 Links.

Plant the Instrument at a , and bring the Index to 360 on the Limb, and turn the whole Instrument about (whilst the Needle hangs in the Direction of the Meridian) till 360 in the Box is brought directly against the North-End of the Needle, and there fix the Instrument ; then is the Telescope set in the Direction of the Meridian also, and in this Position is the Instrument to be planted at every Station.

Now turn about the Index till the Hair in the Telescope cuts the Mark left at \odot , and note in the Field-Book the Degrees and Minutes which the Index cuts on the Limb. *viz. 207 Deg. 20 Min.* being the Quantity of the Angle which the Line $a \odot$ makes with the Meridian.

Remove the Instrument from a , leaving a Mark at that Station, and proceed with the Chain to b , and there plant the Instrument ; then bring the Index to 360 on the Limb, and 360 in the Box exactly to the North End of the Needle as aforesaid, and direct the Telescope to the Mark left at a , and note the Degrees and Minutes cut on the Limb by the Index, *viz. 285 Deg. 10 Min.* which is the Bearing of ba or Quantity of the Angle which that Line makes with the Meridian.

It would be needless to repeat the Manner of measuring the other Lines and Angles in this Figure; but observe that when the Instrument is fixed in the Direction of the Meridian, we frequently observe the Needle by moving it from the Point at 360 with a Knife, &c. then if it swings backward and forward freely without jogging or stopping, and settles again to 360 exactly, we may conclude the Instrument is right in the Direction of the Meridian to make an Observation.

If you suspect the Needle to be acted upon by some hidden magnetic Power, as when you are surveying in mountainous Lands, where there may possibly be Iron Mines in the Earth, which will attract the Needle, you may observe whether or no it be drawn aside in the following Manner.

As when the Instrument was planted at *e*, the North End of the Needle pointing to 360 in the Box; after the Bearing of *e d* was noted, direct the Telescope forwards to *f*, and note the Angle which the Index cuts on the Limb, viz. $200^{\circ} 50'$: Then the Instrument being planted at *f*, because the Bearing of *ef*, observed at *e*, is more than 180° ; subtract 180 therefrom, and to the Remainder $20^{\circ} 50'$ set the Index on the Limb: But, if the Bearing of *ef* had been less than 180, add 180 thereto, and to that Number bring the Index on the Limb. Now turn about the whole Instrument till the Hair cuts the Staff left at *e*, and then, if the North End of the Needle points to 360, as at the last Station, the Bearing of that Line is truly observed.

For, the magnetic Power that attracts the Needle being supposed at a great Distance, the Direction on such a Piece of Land as is commonly surveyed by the Theodolite, will be the same: But if the attractive Power be near the Instrument, the Needle will incline thereto.

The Bearings, &c. of the several Station-Lines in this Field are, *viz.*

<i>Lines</i>	<i>Links</i>	<i>Sta.</i>	<i>Deg.</i>	<i>Min.</i>
<i>a</i> \odot	600	———— <i>a,</i>	207	20
<i>b</i> <i>a</i>	500	———— <i>b,</i>	285	10
<i>c</i> <i>b</i>	1000	———— <i>c,</i>	190	00
<i>d</i> <i>c</i>	500	———— <i>d,</i>	91	55
<i>e</i> <i>d</i>	500	———— <i>e,</i>	125	20
<i>f</i> <i>e</i>	1600	———— <i>f,</i>	20	50
\odot <i>f</i>	500	———— <i>o,</i>	289	15

S E C T II.

An easy Method of protracting any Observations made in the Field by the Needle.

BY the Method here laid down, a Plan of any Field may be drawn on the Paper from one Meridian only, and all the Angles therein laid down by once applying the Protractor to that Meridian, and the Help of a parallel Ruler, being very exact and expeditious.

Provide a circular Protractor, whose Numbers increase the same Way as on the Limb of the Theodolite, and a parallel Ruler of a convenient Length: Then draw a Right-Line N. S. *Fig. 36.* (with a black-lead Pencil) for a Meridian, and assign a Point therein, as at \odot , to which Point apply the Center of the Protractor, and turn it about till the Diameter lies on the Line N. S. with 180 towards N. (that Part of the Limb of the Theodolite being now kept Northward in the Field.

The Protractor being held in this Position, lay the Field-Book before you, and against 207 *Deg.* 20 *Min.* the Bearing of the first Line *a* \odot , close to the

the Limb of the Protractor, make a Mark with the protracting Pin or Needle, and close to that Mark write *a* with a black-lead Pencil.

Hold the Protractor in the same Position, and against 285 Deg. 10 Min. the Bearing of the next Line *b a*, make a Mark with the protracting Pin, and close to that Mark set *b*.

In the same Manner, keeping the Diameter of the Protractor close to the Meridian as it was at first laid; make a Prick with the protracting Pin, close to the Limb of the Protractor, against the Bearing of each respective Line as noted in the Field-Book, and close to each Prick set the Letter or Number of that Line; so against 190 Deg. the Bearing at *c*, make a Prick and write *c*; against 91 Deg. 55 Min. write *d*; against 125 Deg. 20 Min. write *e*, &c. *Vide Fig. 36.*

Having marked the Bearing of each Line round the Protractor, lay it aside, and apply the Edge of your plotting Scale to \odot at the Center, and *a* marked by the Limb of the Protractor; the Beginning of the Numbers coinciding with \odot , and increasing towards *a*; and prick off 6 Chains the Length of the Line $\odot a$, and with Ink draw the Line $\odot a a$.

Lay the parallel Ruler to the pricked Line $p \odot b r$, so that the Edge cuts the central Point at \odot and the Point at *b*, as marked by the Limb of the Protractor; and move it parallel till the Edge cuts the Point at *a* in the Line $p a b r$, and with the Point of your Compasses draw the occult Line $p a b r$ by the Edge of the parallel Ruler; then because the Length of the Line *a b* is 5 Chains, lay the plotting Scale to *a*, and prick off 5 Chains, and draw the Line *a b*.

When you had drawn the occult Line $p a b r$, through the Point *a*, you might set *a b* thereon towards *p* as well as towards *r*; but if you observe in what Direction the Letter *b*, as marked by the
Limb

Limb of the Protractor, stands from the central Point \odot , in the same Direction must the Line $a b$ be set from the Station Point a ; also when the Ruler is laid to the Station b , you cannot be at a Loss whether you should draw the Line $b c$ upwards or downwards, if you observe in what Direction the Letter c stands from the central Point \odot ; therefore in the same Direction draw $b c$ from b .

Lay the parallel Ruler to the central Point \odot and the Mark at c , and move it parallel in that Direction, till the Edge cuts the Point b at the End of the Line $a b$; and by the Edge of the parallel Ruler draw an occult Line, setting thereon from b 10 Chains, and draw the Line $b c$.

Again lay the Edge of the parallel Ruler to the Point at the Center \odot and to the Mark at d , and move it up to c , and draw $c d$.

In the same Manner deal with the other Lines and Angles, so shall the last Line $f \odot$ cut through the Point \odot , and its Length be 5 Chains, as noted in the Field-Book, which proves the Plot to be truly laid down.

In these Observations the Station-Lines only are inserted; the Off-sets from thence to the Boundaries are omitted, because the Manner of plotting them hath been laid down before.

When the Boundaries of the Field are drawn, and the Name thereof entered in the Middle of the Plot, you may with a Piece of Bread rub off the Marks that were made with the Pencil round the Edge of the Protractor and meridian Line, so will the Plot be ready for casting up.

But, if several Fields are to be plotted together, you must draw a Line through the first Station Point in each, parallel to the Meridian in the first Plot, from which the Plot of each Field may be laid down in the same Manner as *Fig. 36*.

Observe,

Observe, neither the Circle nor Figures, expressing the Angle which each Line makes with the Meridian, are used in Practice, though inserted in the Scheme to demonstrate the Nature of the Work. Note also, if you lay the Edge of the thin plotting Scale close to the Edge of the parallel Ruler, and move it forwards on the Paper with the parallel Ruler, till the Edge of the Scale cuts the Point at *a*, and bring the Beginning of the Numbers on the Scale to the Point *a*, you may draw the Line *a b* by the Edge of the Scale held in that Position to 500 the Length of the Line, without drawing any other but the Station-Line itself. Or, the said Scale may be drawn on the Edge of the parallel Ruler itself.

S E C T. III.

An expeditious Method of calculating or casting up the Area of a Plot of Land in Acres, &c.

ACcording to the Rules before-mentioned in Chap. 2. the whole Plot must be reduced into Trapezias and Triangles, and the Length of each Base and Perpendicular measured by the Scale; but since it is often necessary to lay down the Plot by a small one, as $\frac{1}{4}$ of an Inch or less; if you err 8 or 10 Links in taking off the Length of the Bases and Perpendiculars (which may easily happen, if the Lines be not drawn very neat and small) and there being several such Bases and Perpendiculars, the Error may be considerable in the whole Plot: and then also the Base and Perpendicular of each of these Triangles must be multiplied together severally, and their Products added together for the whole Content,

Whereas

Whereas by this Method the whole Plot (let it consist of many Sides or few) is cast up by applying the Scale but to one Base and one Perpendicular, and consequently by one Multiplication, and the Truth of the Work is demonstrated by the Lemma, Page 15. viz. *That Parallelograms (and consequently Triangles) constituted upon the same Base, and between the same Parallels, are equal.*

Let the four-sided Figure $abcd$, Fig. 37. be reduced to a Triangle, whose Area shall be equal to that of the four-sided Figure.

First extend one of the Sides as cd , then lay the parallel Ruler to the Points a and d , and move it parallel till the Edge cuts the Point b , then by the same Edge make a Mark in the extended Line cd at e : Lastly, lay a straight Ruler to the Points e and a , and draw the Line ea , so shall the Area of the Triangle ace be equal to the Area of the four-sided Figure $abcd$.

For the Triangles ade , and adb , having the same Base ad , and lying between the same Parallels, are equal; and therefore the Triangles $abode$ are equal: Wherefore if the Triangle boa is left out of the four-sided Figure $abcd$, and the Triangle doe taken in, and the Areas of these two Triangles being equal, it follows, that such an equal Quantity of Space is left out in one Part of the Figure as is taken in on the other, and the Area must still be the same.

Again, let Fig. 38. be reduced into a Triangle.

First extend the Line fo , and apply the parallel Ruler to the Points o and b , and move it parallel up to the Point a , and, where the Edge cuts the extended Line fo , make a Mark at g ; then lay the Ruler to the Point g and c , and move it up to b , and make a Mark in the extended Line or Base at h .

Lay the Ruler to the Points b and d , and move it to c , then make a Prick in the Base at i .

Lay the Ruler to the Points i and e , and move it to d , and make a Mark in the Base at k .

Lastly, draw the Line ke , so shall this seven-sided Figure be reduced to a three-sided one whose Areas are equal; so may the Triangle fek be cast up by one Multiplication only.

But note, instead of laying the Ruler to the Points i and e , if you had laid it to d and f , and moved it up to e , and drawn the Line zd ; the Triangle zdi would have contained the same Area as fek ; and this often is necessary to prevent the Sides of the reduced Triangle being extended too long, and making the Angles thereof too acute.

Apply the same Scale by which the Plot was laid down to the Base, and measure its Length, also measure the Length of the Perpendicular; multiply these two Numbers together, the Half of their Product will be the Content of the Plot in square Links, which reduce into Acres, &c. as before directed.

Also observe that we commonly chuse to extend one of the shortest Sides of the Plot for the Base of the Triangle, as the Side fo , which we draw with a black-lead Pencil, as ok , as well as ke , id , or zd , and rub them off again with a Piece of Bread, as soon as the Content of the Field is entered with its Name in the Middle thereof.

If in using the parallel Ruler at the first Trials you find it apt to slip on the Paper, which you may do if you be not very careful to hold it close down to the Surface, that Inconvenience may be prevented, if you make Use of three small Pins or Needle, thus: Stick the three Pins in the three first Angles, as at o , a and b , then apply one of the inner Edges of the parallel Ruler to the first and third o and b , and move the other inner Edges to the second at a ; take
out

out the Pin at the second, and put it in the Base or Line extended where the Ruler cuts it at g ; again, lay the Ruler to this Pin at g ; and to another at the fourth Angle at c , and move the Ruler to the fifth Angle at d ; take out the Pin at d , and stick it in the Base at b , and proceed in this Manner with the rest till the Plot is reduced.

S E C T. IV.

Shewing how to reduce the irregular Boundaries of a Field to strait Lines, in order to find the Area thereof.

LET $abcdefgbik$, Fig. 39. represent the Boundaries of a Field, whose Content is desired. First, produce some one of the longest Sides, as ik , then lay the parallel Ruler from the Angle i to g , the next, but one, and move it up to the Point b , and where it cuts the Line produced, make a Mark at r , and draw the strait Line rg , and it will reduce that Side of the Figure, bounded by the two Lines ib and bg , to another bounded by rg one Line only.

In like Manner rg being produced, and the parallel Ruler laid from g to e , and moved up to the Angle f , the Edge cuts the extended Line rg at y ; 2dly, lay the Ruler from y to d , and move it up to e , and it will cut the extended Line rg at z ; 3dly, lay the Ruler from z to c , and move it up to d , and where it cuts the extended Line rg , make a Mark at x ; lastly, draw the strait Line yc , so shall the Side gc which consisted of the four Lines gf , fe , ed , and dc , be reduced to the Side yc , consisting of one Line only; and in like Manner might we proceed, if the Lines were never so many: So may the ten-sided Figure be reduced to a four-sided

sided one, and then to a Triangle which may be cast up by one Multiplication only.

This is the same Method with that before laid down for reducing a many-sided Figure to a Triangle ; but if you have not a parallel Ruler do thus :

Having produced the Side $k i$, lay the Edge of a strait Ruler from i to g , then take with a Pair of Compasses the Distance from b to the Edge of the Ruler, and with this Distance let one Point of the Compasses move gently close to the Ruler, while the other traces out a Line parallel to it, and crosses $k i$ at r , and draw $r g$ as before.

In the same Manner deal with the other Sides, using the Compasses, as here directed, instead of a parallel Ruler.

Or you may get a Plate of thin Brass in Form of an Arch, near whose Ends let there be drilled small Holes, thro' which string it with a very fine Hair ; and then if an Hedge, as $g c$, *Fig. 39.* bends in and out in several Places, and those Bends contain very small Spaces, lay the Hair over it lengthways, so that the Quantities cut off from the Figure thereby may be equal to those added to it, and with a protracting Pin near the Ends of the Hair make two Marks, through which draw a strait Line, and so will this irregular Side be reduced to a regular one : And here it may be observed, that in very small Bends, you may judge by the Eye as near as you can come with the parallel Ruler.

But, if Hedges consist of large Curvatures, chuse out such Points, and so many of them that Right-Lines drawn from Point to Point may vary the Area by such Quantities only as may be rejected, and herein the Hair will be a ready Assistance.

S E C T. V.

The Manner of reducing hypotenusal to horizontal Lines.

WH E N we meet with an Hill in Surveying a Piece of Land, we can only measure the hypotenusal or slope Lines thereof, on the Superficies of the Hill, which are considerably longer than the base or level Lines on which the Hill is situated; as the Lines $a b$; $b c$, *Fig. 40.* are longer than $a o$, $o c$: Therefore when we plot this Hill (because we cannot make a convex Superficies upon a Piece of plain Paper) we must reduce the hypotenusal to horizontal Lines, that all the Lines in the Plot may be laid down alike *in plano*.

For the Lines of Level only must be expressed in a Plot, that every Field therein may lie in its true Situation; for if $a b$, and $b c$, were laid down on Paper as measured in the Field, they would reach to d , and not only thrust the next Hedge out of its true Position, but also take up a great Space in the next Field, making that too little.

Note, Before hypotenusal Lines can be reduced into horizontal, the Angle of Elevation or Depression must be taken; and for this Purpose an Arch should be fixed on the Index of the Instrument, so as to give the vertical Angles at the same Time the Index itself shews the horizontal ones on the Limb.

Let *Fig. 40.* represent an Hill; at the Foot of which the Theodolite is planted, which being set level in order to measure the Angle at a , elevate the Telescope to the Mark at b (which must be set the same Distance from the Ground as the Telescope is (and, when the Hair cuts the Mark at b , the Index shews the horizontal Angle on the Limb, and the vertical

vertical Arch the Angle of Elevation $b a o$, 25 Deg. 50 Min. both at the same Time; which note in the Field-Book one over-against the other.

The Instrument being removed from a , and planted level on the Top of the Hill at b , depress the Telescope to the Mark at c , and the \angle of Depression will be 21 Deg. 34 Min. The Length of ab , as measured up the Hill, by the Chain is 1200 Links, and $b c$ 1416.

In order therefore to plot these Observations, first, draw the right Line $a d$, but do not set the Length 1200 Links thereon, because the Angle of Elevation is noted in the Field-Book against the horizontal Angles, which shew that this Line is to be reduced to a Level; therefore lay the Center of the Protractor to a , the Diameter coincident with $a d$, and against 25 Deg. 50 Min. the Angle of Elevation, make a Mark, and through it draw the obscure Line $a b$, setting thereon 1200 Links the Length of the Hypothenuse, at the End of which make a Mark at b .

Having drawn the Angle of Elevation $b a o$, take a square Protractor or any other Square that hath one right Angle and two strait Edges, and apply one Edge thereof to the right Line $a d$, whilst the other Edge cuts the Point b in the obscure Line $a b$, and thereby let fall a Perpendicular from the Point b , which falls on the Line $a d$ at o ; so shall the Line $a o$ be the true horizontal Line which must be laid down in the Plot.

In the same Manner reduce the Hypothenuse $b c$, by first drawing the Angle of Depression $d o e$, 21° 34', setting the Length of the Hypothenuse $b c$ 14 Chains 16 Links on the obscure Line $o e$, and where that Length 1416 Links reaches from o , make a Mark at e . Lastly, from e let fall a Perpendicular on the Line $o d$, which falls at c ; so shall the Line $o c$ be the true horizontal Line.

H

Or

Or else having noted the Quantity of the Angles of Elevation, and Length of the Hypothenuſe in the Field-Book, you may find the horizontal Line by the Help of the following Table.

A Table ſhewing how many Links to deduct from every Chain's Length in the Hypothenuſal-Line.

Deg.	Min.	Links	Deg.	Min.	Links	Deg.	Min.	Links
4	3	$\frac{1}{4}$	19	57	6	29	32	13
5	44	$\frac{1}{2}$	21	34	7	30	41	14
7	1	$\frac{3}{4}$	23	4	8	31	47	15
8	6	1	24	30	9	32	52	16
11	29	2	25	50	10	33	54	17
14	4	3	27	8	11	34	55	18
16	16	4	28	21	12	35	54	19
18	12	5				36	52	20

Having the Angle of Elevation 25 Deg. 50 Min. and the Length of the Hypothenuſe *a b* 12 Chains given, thence to find the Length of the horizontal Line.

Look in the Table for 25 Deg. 50 Min. and againſt it you will find 10 Links, and ſo many muſt be deducted out of every Chain in the Length of the Hypothenuſe; then if 1 Chain or 100 Links require 10 Links to be deducted from thence, 12 Chains or 1200 Links require 120 Links to be deducted; therefore ſubtract 120 Links from 1200, the Remainder is 1080, the Length of the horizontal Line *a v*.

Again, the Angle of Depression at *b* is 21 Deg. 34 Min. and the Length of the Hypothenuſe or ſlope Line *b c* 1416 Links, you will find in the Table againſt 21 Deg. 34 Min. 7 Links; then if 100; 7 :: 1416 : 99; therefore ſubtract 99 Links out of 1416.

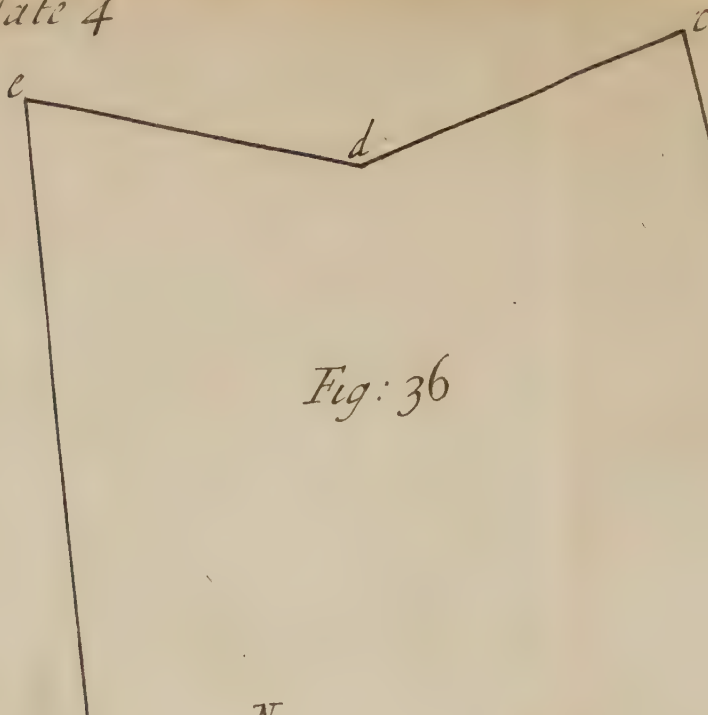


Fig. 36

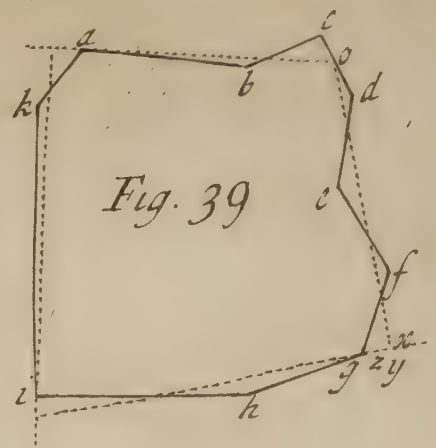


Fig. 39

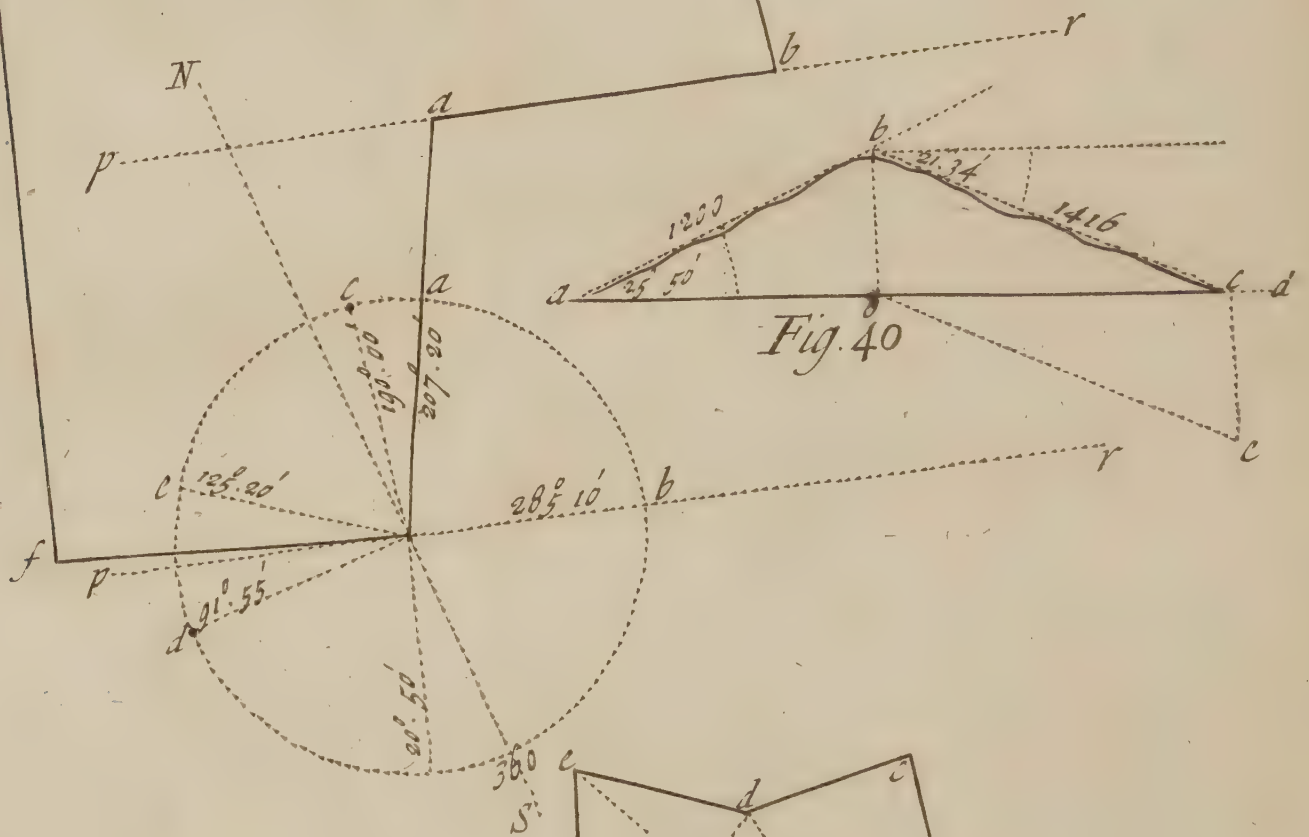


Fig. 40

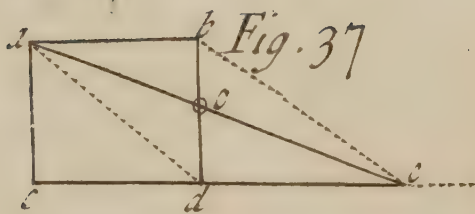


Fig. 37

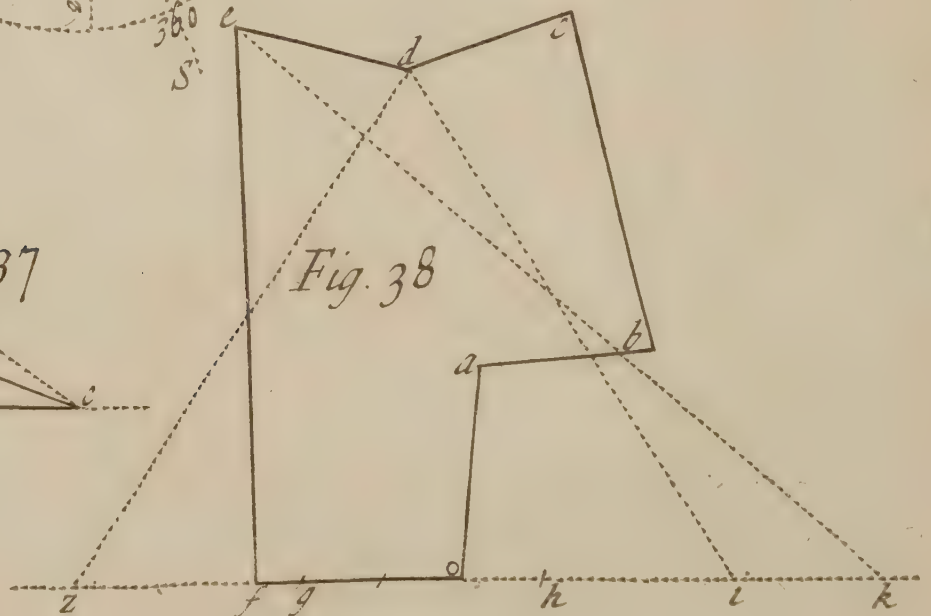


Fig. 38



1416 the Length of the slope Line, the Remainder is 1317 Links, the Length of the level Line *o c*. But if you cannot find the given Angle of Elevation in the Table, make use of that which approaches nearest thereto; and *note*, Surveyors in Practice seldom take notice of a gradual Ascent, if it does not make an Angle of 5 or 6 Degrees or thereabouts; the Difference between the slope and level Line being then inconsiderable, except in some extraordinary Case, and then 'tis safest to make use of the first Method here laid down, because the Table is too short: but if you have a correct Table of Sines and Logarithms, you may make use thereof.

If you are working with the Chain, and would find the horizontal Line of an Hill, you may carry a small Quadrant in your Pocket, with which measure the Angle of Altitude, and note it in the Field-Book against the horizontal Angle observed at that Station (but let the Mark be set the same Distance from the Ground with your Eye when you observe the Angle of Altitude) and proceed to reduce the Line as aforesaid.

Also you may observe an Angle of Altitude if you have only the Plain Table in the Field, by turning it down into the Notch of the Ball and Socket, making it stand perpendicular by applying the String and Plumbet thereto, and then the Index and Sights screwed to the Center of the Table may, indifferently serve the Turn; but a Quadrant is better.

Remember to shade over that Part of your Plot where the Lines are thus reduced with the Representation of Hills, lest another Person should measure them by the same Scale with the other Lines, and find them to differ.

If a Field hath the Bottom and Top Lines level, and both Sides rising alike, it is to be accounted but

as a declining Level, and to be measured as a level Ground in regard of the Quantity of Superficies, through the Side Lines must be reduced, to make a regular Plot in respect of the adjacent Fields that are level : But if a Piece of Ground be level at one End, and both Sides, and an Hill rising up along the Middle, or if there be several Hills in the Middle, the Superficies thereof will be more than in a Plain bounded by the same Limits.

Now Surveyors differ in their Opinion in respect of casting up the Content of such a Field ; some argue on the Tenant's Behalf, that since all Vegetables stand in a perpendicular Direction on the Earth (that is, grow strait upwards) as much will grow on the horizontal Line as on the Hypothenuse, and therefore the Lines ought to be all reduced to a Level, and the Content to be deduced from the Plot so laid down.

Others say, that there ought to be Marks placed on the Top of the most remarkable Hills, and the Chain drawn over Hill and Dale, and the slope Lines laid on the Paper of the same Length as measured in the Field, and the true Content in Acres, &c. deduced from thence ; although the Slopes be reduced afterwards, that the Field may be laid in its true Situation in respect of others adjacent in the fair Plot.

'Tis hard to determine which Way is to be practised in all Cases ; for, though by the last Method you will have the true Quantity of Superficies more nearly given, yet the Allowance in the first is often but reasonable, if the Soil of the Hills is not so profitable as if the whole Field was situated on a Plain ; but the Reader may use which he shall think most proper.



C H A P. V.

Shewing how to survey and make a perfect Draught of several Pieces of Land lying together as a Manor, &c. Also how to compare the Bearings and Angles one with another, at each Station, as observed by the Theodolite, in order to correct any Error that may arise in measuring the Angles in the Field, as well as protracting them on Paper.

S E C T. I.



HAVING in the former Chapters laid down the best and most practical Methods for measuring any Piece of Land by the most proper Instruments, I shall here subjoin the Manner of surveying several Parcels lying together; an Example of which may be taken from the small Tenement or Farm, *Fig. 41.*

First, I take a View of the Land, considering at which Part thereof it will be most convenient to begin, and proceed with the Work; and because 'tis best working in a *Lane*, as often as an Opportunity

presents ; therefore I set up the Theodolite at $\odot 1$ in *Charlton* Field.

Then I enter in the Field-Book the Title of the Survey, and in the middle Column $\odot 1$, and then find a Station-Staff forwards in the *Lane*, as far as I can see distinctly (the farther the better) as to $\odot 2$ (and when the Station-Lines are within the Field I send the Staff to the next eminent Bend in the Hedge, or even to the farther End thereof, if the Line from the Instrument to the Staff be not at too great a Distance from the Hedge, so as to cause Off-sets greater than a Chain, or a Chain and half, or thereabouts ; for Off-sets taken too long are not so easily laid off at right Angles from the Station-Line :) I direct the Telescope to the Staff at $\odot 2$, and note the Degrees in the Box cut by the North End of the Needle, *viz.* 356 Deg. 10 Min. which I enter in the Field-Book, for the Bearing of this first Station-Line.

Then I set up a Staff in the Hole over which the Center of the Instrument was placed, to which Staff I direct one of my Assistants to apply the Ring at one End of the Chain, whilst the other Assistant stretches it out in a right Line towards $\odot 2$; letting it lie on the Ground in that Direction, till the Occurrences in this Chain's Length are entered in the Field-Book, *viz.* I measure the Distances of the Chain from the Boundaries of each Field, which I enter in the Columns of Off-sets ; that on the right Hand of the Chain in the right Hand Column, and that on the Left in the left Hand Column. If the Land is Part of that which I am about to survey, I write in one of the outside Columns by what Name it is called ; but if it belongs to a Stranger, I write the Name of the Owner thereof, and in all Cases express to which Land the Hedge belongs.

So, at the Length of 20 Links from $\odot 1$, I lay the Off-set Staff at right Angles with the Chain, and measure

measure the Distance from thence to the Corner of *Turfy-Lease*, which I find to be 15 Links; therefore in the middle Column representing the Station-Line I write 20, and against it in the right Hand Column of Off-sets I enter 15: Likewise when I come to 40 Links in the Chain-Line I am against the Corner of *Cow-pasture*; therefore I lay the Off-set Staff to the Chain, and measure the Distance from thence to the Corner of *Cow-pasture* 80 Links, which I enter in the left Hand Column of Off-set against 40 in the middle Column; denoting, that, at the Length of 40 Links from $\odot 1$, the Off-set 80 Links reached the Corner of *Cow-pasture* on the left Side of the Station-Line.

The Hedges on each Side the *Lane* running on very nearly strait from these Corners, I take no more Off-sets in this first Chain's Length, nor at the second: But when I have laid the Chain a third Time, and come against 80 Links, I there take an Off-set on the left Hand of the Chain-Line, because the Hedge varies its Direction, making a considerable Bend; for, though the Distance from the Chain to the Hedge continually varies from the Corner to this Place, yet I only take Off-sets at each End, omitting the intermediate Parts; since, when the Extreams of a right Line are given, that right Line is also given. But when the Hedge runs on with a continued, but irregular Curvature; then I take Off-sets at every Chain, or half Chain's Length, or oftener, as the Thing requires.

In this Manner I proceed with the Chain till I come to the Staff at $\odot 2$; observing, as I go along, the Bends in the Fences on each Side of the *Lane*; to every one of which I take an Off-set, and then write the Length of each on the right or left Side of the middle Column in the Field-Book, representing the Station-Line, according as they were laid off in the Field.

Note, the Mark \odot in the Field-Book denotes a Station ; B a Bearing ; \angle an Angle ; *cu.* the Cutting of an Hedge by the Chain ; *ag* some remarkable Object on the farthest Side of the Hedge, as another Fence shooting up thereto ; *ret.* Return to a former Station, &c.

Being come to $\odot 2$, I there plant the Instrument, and send the Station-Staff forwards in the *Lane* as far as I can see it, as to $\odot 3$; and then bring the Index to 360 on the Limb, and, turning the whole Instrument about, I direct the Telescope to the Staff left at $\odot 1$, and there fix the Instrument. Then having turned about the Index on the Limb, till through the Telescope I see the Staff at $\odot 3$, I find that the North End of the Needle points at 338 Deg. and the Index cuts on the Limb 161 Deg. 50 Min. therefore under 2, in the middle Column of the Field Book, I enter 338 Deg. and under that 161 Deg. 50 Min. denoting that at the second Station the Bearing of the third from thence is 338 Deg. and the Angle which the Index cuts on the Limb is 161 Deg. 50 Min.

The Rule I observe in measuring each Angle is this :

First, I bring the Index to 360, and with that Part of the Limb towards me, I direct the Telescope to a Mark at the last Station, and there fix the Instrument ; then I turn about the Index on the Limb till I see the Hair in the Telescope cut a Mark at the next Station before me ; so shall the Needle shew the Bearing of the next Line, and the Index on the Limb shews the Quantity of the Angle at the present Station.

The Angles and Bearings of the Lines are taken at once setting the Index, as easily and expeditiously as the Angle itself only ; therefore insert the Bearing of each Line in the Field-Book, as you see in the Form thereof ; for then you may prove the

Truth

Truth of your Work in the Field at each Station, before you leave it, by one of the following Rules:

If to the present Bearing, be added 180 Degrees, and from the Sum you subtract the last Bearing, then the Remainder will be the present Angle.

O, if to the present Angle you add the last Bearing, and from the Sum subtract 180, then will the Remainder be the present Bearing.

But, if the Degrees to be subtracted are more than those from which they are to be subtracted, the latter must be increased by 360, and then subtract. And, if the Remainder be more than 360, then abate 360, and the Result gives the Degrees required.

So at $\odot 2$, if to the present Bearing $338^{\circ} 00'$ you add 180° , the Sum is $518^{\circ} 00'$; from which Sum, if you subtract the last Bearing at $\odot 1$, $356^{\circ} 10'$, the Remainder is $161^{\circ} 50'$, equal to the present Angle.

Likewise, if to the Bearing at $\odot 3$, $1^{\circ} 30'$, you add 180 Degrees, the Sum is $181^{\circ} 30'$, which is less than $338^{\circ} 00'$, the Bearing of the last Station; therefore $181^{\circ} 30'$ must be increased by 360, and then the Sum is $541^{\circ} 30'$, from which if you subtract 338, the Bearing of the last Station, the Remainder will be $203^{\circ} 30'$, equal to the present Angle.

In like Manner may any other Angles be examined, and, if found erroneous, the Error may be corrected, before 'tis communicated to the following Part of the Work.

Therefore when you have noted the Bearing of the present Station, write it in one of the outside Columns of the Field-Book, and adding 180 thereto, subtract the Bearing at the last Station therefrom; and then, if the Angle thus calculated from the Bearings agrees with that which the Index cuts on the Limb, you may conclude the Angle is
rightly

rightly observed, and therefore may be entered in the Field-Book.

But observe, tho' the Numbers thus compared will be very nearly alike, yet sometimes they may differ some few Minutes, because the Divisions in the Box being so much smaller than those on the Limb, the Degrees and Minutes cannot be estimated alike in both; but yet you will be sure always to correct and avoid any gross Error before you proceed with the following Work; and to this End the before-mentioned Rules are of excellent Use.

These Directions I shall not repeat, though I make use of them throughout the whole Work, unless any thing new occurs in measuring of the other Lines and Angles, referring the Reader rather to the Field-Book and Plan of the Work, than tiring him with Repetitions.

Note, the chief, if not the sole Use of taking the Bearings here by the Needle, is for the Sake of protracting from the Meridian: And because the Needle is subject to err a little, therefore whenever the Bearings and the Angle, after they have been calculated one from the other, (according to the preceding Rules) are found to differ, if this Difference does not exceed a Degree or thereabouts, the Bearings must be corrected from the Angle; for in taking the \angle there can be no sensible Error, if the Cautions given in Page 58 be duly observed. But if the above-mentioned Difference be considerable, and the Needle be not very faulty, you may conclude that some Mistake hath been committed, which must be inquired into before you proceed any farther.

From $\odot 2$ I proceed with the Chain towards $\odot 3$; but, at twenty Links in the first Length from $\odot 2$, I am against the Hedge that parts *Horne-close* from *Turfy-Lease*; therefore I take an Off-set thereto perpendicular from the Chain-Line, and enter in
the

the Field-Book *ag* 17 Links, and this will hereafter be of Use in closing the Plot.

Being come to $\odot 3$, I there observe and prove the Bearing and Angle at that Station, and then proceed with the Chain towards $\odot 4$; but first, at \odot or the present Station, I measure an Off-set to the right 10 Links, and to the left 20 Links; at 41 in the Chain Line, I am against the *Orchard-Hedge*; at 204, the *Orchard Pales*; at 261, I am against the *Gate* that leads into the *Yard*, and also against another that goes into *Cow-Pasture*; therefore to each of these Remarks I measure an Off-set from the Chain-Line, and enter them into the Field-Book.

In going from $\odot 4$ to $\odot 5$, the Chain touches the Brow of the Ditch at 2 Chains 20 Links from the last Station; therefore against 220 in the Field-Book I write *o*, denoting that there was *o*, or no Distance from the Chain to the Ditch. By the Brow of the Ditch is meant the determined Distance of 5 Links from the Stem of the Hedge.

Being come to $\odot 6$, I send a Staff to the farther Side of the Field called the *Stockin*, and if I cannot see the Mark through the Hedge, I cause the Bows to be removed or held back till I can plainly see the Mark; but if that cannot be done, I make my Station a little on this Side, or else beyond such a thick Place till I can plainly see the Mark, and draw the Chain through the Hedge in a strait Line, and where it cuts the Hedge I write *cut*, as here it does at 10 Links; but, if the Fence is a Wall, I allow for the Thickness thereof, and always measure the nearest Distance between Station and Station that can possibly be.

Being come to $\odot 9$ in the *Stockin*, I cause a Staff to be set up in the very Corner of the Field next the Lane where the Boundaries meet, to which I measure from $\odot 9$; so shall the End of this Line coincide with the Off-set which I took to this Corner from the
Station-

Station-Line in the Lane, which will be a Proof that the Work is truly laid down, when I come to protract it.

If upon a Piece of Paper with the Pen only you make an Eye-draught of the *Lane*, and that Field which you have finished, setting your Station-Lines with their Numbers, as you made them in the Field; you will plainly see your Work as you go along, and be able to distinguish which Boundaries of the present Field are already measured in the precedent, as well as be directed, with a great deal of Ease, how to proceed with your Work, when you come to protract it.

Having made all the necessary Observations round the *Stockin*, I return to $\odot 9$; and with 360 on the Limb towards me, I direct the Telescope to a Mark at the last Station before I came to this, *viz.* $\odot 8$, and fixing the Instrument there, I next direct the Telescope to $\odot 10$, and note the Angle and Bearing at that Station: Then I lay the Chain through the Hedge from $\odot 9$ towards $\odot 10$, and take an Off-set to the Fence where each Partition-Line joins it on the other Side; by the Help of which, together with the other Off-sets on the further Side in the *Lane*, most of the inward Fences of the *Orchard*, *Garden*, &c. may be drawn.

From $\odot 10$ I cannot see into the very Corner next the *Lane*, therefore I take an Off-set thereto 20 Links from the Station-Line, and so are the Out-Lines of the *Garden*, *Yard*, &c. finished.

Then I return to $\odot 8$ in the *Stockin*; and here it may be observed, that when I design to return to any Station, before I leave it, I cut up a Turf with a little Paddle, which I fix in one End of the Off-set-Staff, or make some such Remark that I may be sure readily to find the Place in which the Station-Staff before stood; and in the Field-Book to this Mark \odot I write *return*. Then planting the Instru-
ment

ment at $\odot 1$, I direct the Telescope to the Mark left at $\odot 7$.

Note, I make it a general Rule, to observe the Angle with that Line which was measured immediately before I come to the Station where I took the Angle the first Time : So here I observe the Angle made with $\odot 7$, $\odot 8$; and not with any other, as $\odot 8$, $\odot 9$; therefore according to this constant Rule I direct the Telescope back to $\odot 7$ in the *Stockin*, and, fixing the Instrument there, I next direct the Telescope to $\odot 11$ in *Home-Close*, and *note* the Angle, &c. as in the Field-Book.

After I have measured the Angle, &c. at $\odot 11$, and am going forwards towards $\odot 12$; at 76 Links of the Chain I perceive myself over-against the Fence that parts *Out-Wood* from *Crabtree-Close* : I therefore ask the Follower of the Chain, how many Arrows he hath in his Hand, he answers 4 ; therefore I enter in the middle Column of the Field-Book 476 ; and against that on the left I write 61, the Length of the Off-set ; denoting, that at the Length of 4 Chains 76 Links from $\odot 11$, I laid off an Off-set to the left, 61 Links. Then I proceed to observe and enter in the Field-Book the rest of the Occurrences round *Home-Close*, closing it at the End of the Line from $\odot 12$, next the *Lane*.

Then I return to $\odot 12$, and proceed to $\odot 13$, closing *Turfy-Lease* at the Corner ; to which I took the first Off-set from $\odot 1$, in *Charlton-Field*.

In the same Manner I proceed round *Crabtree-Close*, entering the several Occurrences as you find them in the Field-Book.

Being at $\odot 17$, I cause a Staff to be set up close to the Fence where the Hedges join one another near $\odot 7$; to which Staff I measure strait from $\odot 17$, closing *Out-Wood* at the Extremity of the Station-Line, which coincides with the Off-set laid off from $\odot 7$, in the *Stockin*.

Having

Having finished all the Fields on this Side the *Lane*, I return to $\odot 6$; observing this general Rule, never to make a Tour greater than Necessity requires, but always to close each Field as soon as possible: So instead of going up the *Lane* from $\odot 2$, if I had turned off into *Turfy-Lease*, and closed first *Turfy-Lease*, and then *Crabtree-Close*, &c. the Work had been done as well.

Being at $\odot 6$, I cause a Staff to be set up in a convenient Place, on the farther Side of *Garrot-Field*, as at $\odot 18$, laying the Chain through the Hedge, from $\odot 6$, towards $\odot 18$; and because the Hedge belongs to the next Field, I write Hedge to *Will. Green*, the Owner of the adjacent Land.

After I have observed the Angle at $\odot 18$, I direct the Telescope to a Staff set up by the *River* Side, and note the Degrees which the Index cuts on the Limb, viz. $131^{\circ} 10'$; and then measure from $\odot 18$, to that Staff, 300 Links, taking Off-sets on each Side the Line to the Brink of the *River*, as you see in the Figure thereof; and this will be found very useful in all manner of Practice, where the Boundaries are very irregular, that as much Work may be performed at once setting down the Instrument as possible.

From $\odot 18$, I proceed with the Chain to $\odot 19$, and from thence I measure along the Hedge-Side that reaches from the *River* to the *Lane*; and when I come against the Hedge that parts *Magg-meadow* from *Cow-Pasture*, I write a g 50 Links, being so far distant from the Chain-Line; and because the Hedge from this Place belonged to *Garrot-Field*, I entered it so in the Field-Book, but now it belongs to *Cow-Pasture*; therefore I write *Hedge* to *Cow-Pasture*.

Then returning to $\odot 19$, I direct the Telescope first to $\odot 18$, and then to $\odot 20$, and I find $\odot 19$ to be in a strait Line with $\odot 18$ and $\odot 20$; therefore I enter in the Field-Book 180, or Station-Line continued;

tinued ; then I proceed to observe and enter down the several Occurrences at $\odot 20$, $\odot 21$, and $\odot 22$, round *Mag-meadow*, and then return to $\odot 21$.

From $\odot 21$, I go to $\odot 23$ in *Cow-Pasture*, closing it on the Corner, near $\odot 1$ in *Charlton-Field*; and so is the whole finished, as far as relates to the Field-work.

If there be several Pieces of Land belonging to the same Manor, &c. you are now surveying, that lie dispersed in several Furlongs in common Fields adjacent to the same Manor ; you may from one of your Stations on the Outside of the Plot take the Bearings to each Piece, by causing a Mark to be set up thereon, and measuring the Distance from that Station to each Mark : So may each Piece be plotted in its true Form, and laid in the same Situation in the Plot as on the Land itself : And in your Table of References or Terrier, you may insert the Name of the Furlong where each Piece lies, with the Name of other Persons Land that lies round it, as a Direction to the Steward, or other Person, to find each Piece.

Observations

Observations and Dimensions of Land lying in the Parish
of W——, in the County of L——, Part of the
Estate of — — 31st of March, 1724.

Remarks	Off-sets	Station-Lines	Off-sets	Remarks
⊙ 1 in Charlton-Field.				
Corner of Cow-Pasture, Hedge to Pasture.	B	356° 10'		
	ag. 80	20	ag. 15	Corner of Turfy Lease Hedge to Turfy Lease.
	10	40		
		280		
	18	300	20	
		563		
⊙ 2 in the Lane.				
338° 00'	B	338° 00'		
180° 00'	V	161 50		
518 00	10	0		
356 10		20	ag. 17	Hedge to Home-clofe
161 50		446		
⊙ 3 in the Lane.				
	B	1° 30'		
	A	203 30		
	20	0	10	
1° 30'		41	ag. 10	Orchard Hedge.
180 00		204	ag. 15	Orchard Pales.
181 30	35	261	20	Gate into the Yard.
360 00		290	18	Corner of Barn.
541 30	20	388	ag. 24	Calves Croft Hedge.
338 00				
203 30		435		

<i>Remarks.</i>	<i>Off-sets.</i>	<i>Station Lines.</i>	<i>Off-sets.</i>	<i>Remarks.</i>
<i>Gate into Garrot-Field. Hedge to Field.</i>	B V ag. 20 13 16	$\odot 4$ in the Lane. $349^{\circ} 30'$ 168 00 90 140 220 500 626	0	<i>On Stockin Hedge.</i>
	B V 10 35 30	$\odot 5$ in the Lane. $13^{\circ} 50'$ 204 20 0 64 152 236	20 12 10	
<i>Corner of Stockin</i>	B V 0 6 3 40	$\odot 6$ in the Lane. $93^{\circ} 30'$ 259 40 10 int. Into Stockin. 270 500 750		
<i>Hedge to Wood.</i>	B V 23 60 45 ag. 20	$\odot 7$ in Stockin. $193^{\circ} 30'$ 280 00 00 335 620 668 680		

Remarks.	Off-sets.	Station Lines.	Off-sets.	Remarks.
		⊙ 8 in Stockin.		
	B	229° 00'		
	A	219 20		
Hedge to Stockin	10	0		
	10	268		
		⊙ 9 in Stockin.		
	B	268° 30'		
	A	219 20		
Corner.	30	22		
Hedge to Stockin				
		300	20	Close Stockin here.
		Hedge to Lane, in Corner next to Calves Croft.		
		⊙ 9	ret.	
	B	192° 00'		
	A	143 00		
		20 int.		
		Into Home Clofe.		
		90	20	Calves Croft Hedge.
		220	20	Garden Pales.
		350	20	Corner of Orchard Hedge.
		261		
		⊙ 10 in Home Clofe.		
	B	264° 40'		
	A	252 40		
		205+	20	on Orchard Hedge.
		250	20	close here.
		255		
		Out-lines of Orchard, Garden, &c. close on Hedge next the Lane.		

Remarks	Off-sets	Station Lines	Off-sets	Remarks
	B	⊙ 8 ret. 105° 00'		
	A	91 30		
		19 int.		
		into Home Close.		
Hedge to Wood. corner	5	24		
	37	353		
	28	465		
		⊙ 11 in Home Close.		
	B	193° 30'		
	A	268 30		
	60	130		
Hedge to Home Close	ag. 61	476		
Corner	18	727		
		⊙ 12 in Home Close.		
	B	259° 00'		
	A	246 20		
	ag. 28	65		
	48	268		
		667		Close here.
Close Home, Close on Hedge to Lane, next Turfy- Lease.				

Remarks.	Off-sets.	Station Lines.	Off-sets.	Remarks.
	B V	☉ 12 ret. 189° 20' 176 00 20 int. into Crab-tree Close. 60 612 618 int. Into Charlton Field. 642	55 12	Corner Hedge to Turfy-lease. Corner.
	B V	☉ 13 in Charlton Field. 262 40 253 20 10 510 530 reaches first Station.	28 20	Close here.
<i>Turfy-lease, Closes on Corner of Hedge next the Lane.</i>				
Touch on Hedge to to Crabtree-Close.	B V O 17	☉ 13 ret. 103° 00' 94 00 135 310		
	B V 3 26	☉ 14 in Charlton Field. 69 00 146 00 320 545 618		

Remarks.

Remarks	Off-sets	Station-Lines	Off-sets	Remarks
		⊙ 15 in Charlton Field.		
	B	5° 00'		
	Δ	116 00		
	15	60		
		166 int.		
		Into Charlton Common.		
	120	337		
Hedge to	16	563		
Crabtree Close		645		
		⊙ 16 in Charlton Common.		
	B	276° 35'		
	Δ	91 35		
		16 int.		
		Into Crabtree Close.		
		22	30 Hedge to Wood.	
		710 close here.		
		Close Crabtree-Close to Corner next Home-Close and Wood.		
		⊙ 16, ret.		
	B	10° 20'		
	Δ	185 20		
	22	222		
	60	386		
	69	434		
	50	611		
A Gate into	10	930		
the Wood,	32	1110		
	86	1268		
	142	1353		
		1553		

Remarks.	Off-sets.	Station Lines.	Off-sets.	Remarks.
		⊙ 17 Charlton-Field.		
	B	264° 30'		
	V	74 10		
	128	225		
		318 int.		
		Into Clemenson's Land.		
	56	370		
	25	504		
	12	784		
		1240		
Outwood closes on Corner of Stockin, next to Clemenson's Field.				
		⊙ 6 ret. into Lane.		
	B	270° 50'		
	Λ	77 00		
		28 int.		
		33	10	Hedge to W. Green.
		288	40	
		560	10	
		932	98	Corner to River.
		⊙ 18 in Garrot-Field.		
	B	186° 00'		
	Λ	95 10		
	V	131 10		Angle to a Bend in the River,
		26	75	from ⊙ 18
	56	175	82	
	25	248	53	
		300		
		225		⊙ Touch the River's Brink.
		422	145	
		536	110	
		620	116	

Remarks.

Remarks.	Off-sets.	Station Lines.	Off-sets.	Remarks.
		⊙ 19 in Garrot Field.		
	B	96° 30'		
	A	90 30		
		0	8	Hedge to Garrot Field continued to River.
		180	0	
		390	34	
		558	50	ag. Hedge to Cow-Pasture.
		890	76	
		1024	50	close here.
Close Garrot-Field on Hedge next to Lane.				
		⊙ 19 ret.		
	B	186° 00'		
	A	180 00		
		8 int.		
		Into Mag-Meadow.		
		57	126	
		143	120	
		280	42	
		348	21	
		572	97	
		665	46	
		780	8	A Bridge.
		900	0	
		1004	15	
		1045		

Remarks.	Off-sets.	Station Lines.	Off-sets.	Remarks.
		⊙ 20 in Magg-Meadow.		
	B	151° 00'		
	Δ	145 40		
		78	40	
		154	82	
		280	75	
		395	30	Corner to River.
		⊙ 21 in Magg-Meadow.		
	B	54° 30'		
	Δ	83 35		
		00	28	Hedge to Magg Meadow.
		100 64	64	
		245 78	78	
		380 59	59	
		452 27	27	
		⊙ 22 in Magg-Meadow.		
	B	358° 00'		
	Δ	123 20		
		00	28	
		147	53	A Gate.
		378	28	
		600	6	
		790	30	
		890	60	
		1010	137	Closé here.
		1032		
Magg-Meadow closes on the Corner of the Hedge next Garrot-Field.				

Remarks.

Remarks.	Off sets	Station Lines.	Off-sets.	Remarks.
	B A	Ⓞ 21 ret. 143° 35' 172 25 22 int. Into Cow-pasture		
		93	6	
		244	60	Corner to River.
	B A	Ⓞ 23 in Cow-pasture. 90° 50' 129 05 205 245 302 428 560 680 755 842 936	55 Hedge to Cow-pasture. 60 62 24 20 38 58 45 Close here.	
Cow-pasture closes on Corner next Charlton-Field.				

S E C T. II.

The Manner of Protracting the Observations contained in the preceding Field-Book.

TH E Protractor for this Purpose is best made a whole Circle, and marked on the Limb where the Numbers begin with *N.* or a *Flower-de-luce* ; for then may that Part of the Protractor be kept always one Way as the Instrument in the Field ; and therefore you will be less liable to Mistake, than if you use a Semicircle, which must be laid upwards or downwards, as the Degrees of the Bearing are more or less than 180 : The Diameter of this Protractor may be laid parallel to the Meridians, by the Help of equal Divisions graved on the inner Edge thereof ; or by the Degrees on the outward Edge.

Being provided with a Sheet of strong Cartridge-Paper, or (if that is not large enough) a Skin of Parchment ; or which I reckon better (especially for the fair Plot) if one Sheet of Paper be not big enough, to have several Sheets pasted on Cloth or Canvas well stretched and dried in a Frame before you use it ; and this you may have of any Size, as the Largeness of the Work to be laid down requires.

Or a Practitioner may have Sheets of large Paper printed from a Copper-Plate, with fine Meridian Lines drawn thereon at exact Distances ; and these will be very neat and true, and will save much Trouble in drawing Meridian Lines by a Parallel Ruler, or otherwise.

If you have not a Parallel Ruler, you may draw Lines parallel to one another, by setting one Foot of a Pair of Compasses at or near the End of your given right Line, and with the other describe the Arch of a Circle ; do the same at the other End of the Line,
and

and through the utmost Convex of these two Arches you may draw a Line parallel to the first.

Or if you bend the Paper double, so that the two Ends coincide, and prick Holes through them both; then the Paper being opened, Lines drawn through the correspondent Points will be parallel one to the other.

Having drawn parallel right Lines at convenient Distances throughout the Paper marked with N. S. representing Meridian, or North and South Lines; I chuse out some Place in one of these Lines to represent the first Station, as at $\odot 1$, *Fig. 41*, and lay the Center of the Protractor on the Point $\odot 1$, the Diameter being parallel to the Meridian Line, and the Beginning of the Degrees of the Protractor towards N. or upwards: And because the Bearing of the first Station-Line is $356^{\circ}, 10'$, I make a Mark with my Protracting Pin against that Number, close to the Limb of the Protractor; to which Mark I draw an obscure Line from $\odot 1$, representing the Chain Line from $\odot 1$ to $\odot 2$.

Then the Field-Book being open before me, I lay the Edge of my Plotting-Scale to this obscure Line $\odot 1$ and $\odot 2$; and because I find in the Field-Book that the Off-sets from this Line were laid off at 20, 40, 280, 300, and 563; therefore making the Beginning of the Numbers on the Plotting-Scale to coincide with $\odot 1$, I make a Prick against each of these Numbers close to the Edge of the said Scale; then turning the Scale perpendicular to the Line, I apply it successively to those several Points, and there prick off the Length of the several Off-sets on the respective Sides of the obscure Line; so against the first Mark in the obscure Line, I prick off 15 Links to the Right, which gives the Corner of *Turfy-Lease*: Also against the second Prick in the obscure Line, I prick off 80 Links to the Left, which gives the Corner of *Cow-Pasture*; at 280, or the
third

third Mark in the obscure Line, I prick off 10 to the Left; at 300, 20 to the Right; and at the End of the Line 563 I prick off 18 Links to the Left; lastly, I draw Lines with Ink from Point to Point on the Outsides of this obscure Line, thereby constituting the Boundaries of the *Lane* so far.

At the first and second Distances, I was against the Corners of *Turfy-Lease* and *Cow-Pasture*; therefore, with a Black-Lead Pencil I draw two short Lines, cutting the *Lane*, to denote that the *South* Fences come up to the *Lane* at those Corners, and will hereafter be of Use in closing these Plots.

Having thus finished my first Length, I produce the obscure Line, if Occasion requires, both Ways, till it is as long each Way as the Radius of the Protractor; then I place the Center of the Protractor on the Point $\odot 2$, and turn it about thereon, keeping the Beginning of the Degrees towards $\odot 1$, the last Station, till the Diameter coincides with the Station-Lines $\odot 1$, $\odot 2$; then close to the Edge of the Protractor, right against $161^{\circ} 50'$ the Degrees of the present Angle, I make a Mark with my Protracting-Pin; and to that Mark from $\odot 2$ draw an obscure Line, representing the Station-Line, from $\odot 2$ to $\odot 3$.

And that I may be sure the Line $\odot 2$, $\odot 3$, is drawn in its true Position, I turn about the Protractor, the Center still coinciding with $\odot 2$, till the Diameter be parallel with the Meridians; the Beginning of the Numbers of the Protractor being towards N. on the Meridian Line, and then will the Line $\odot 2$, $\odot 3$, before drawn, meet the Limb of the Protractor against $338^{\circ} 00'$, the Bearing of the Line $\odot 2$, $\odot 3$, which proves the Line $\odot 2$, $\odot 3$, to be truly laid down.

And thus may the Plot be laid down by the Angles, and examined by the Bearings.

The constant Rule I observe in drawing the Angle is this : To lay the Diameter of the Protractor on that Line which brought me to the present Station, where the Angle about to be laid down was taken ; and to keep the Beginning of the Numbers on the Protractor towards the last Station. And, in order to prove that each Angle is truly laid down, I turn about the Center of the Protractor on the Point, representing the present Station, till the Diameter be parallel to the Meridians, with the Beginning of the Numbers towards N. on the Meridian Line ; then will the Line last drawn, cut the Number expressing its Bearing on the Limb of the Protractor, if that Line be drawn in its true Position.

But there will be no Need of this double Trouble in protracting, if the Bearings be carefully examined, and corrected from the Angles, according to the Directions given in the last Section ; it will be best then to lay down the Angles on the Plot from the Bearings in the Field-Book, without at all regarding the Angle observed by the Limb of the Theodolite.

In like Manner, I lay down the Angles taken at the 3d, 4th, 5th, 6th, 7th, 8th, and 9th Stations ; and also the corresponding Lengths and Occurrences : I continue the Boundaries to the several Offsets as I go along, drawing a short Line across them with a Black-Lead Pencil, where the Remarks *ag*, &c. are noted in the Field-Book, and I break off the Fences where there are Gates : So at the last Length, from $\odot 9$, when I have drawn that Line in its true Position, and made it of its just Length, as noted in the Field-Book, I find its Extremity to coincide with that Point in the Fence, to which I laid off an Offset from 388 in the Station-Line $\odot 3$, $\odot 4$, in the *Lane*, which proves that the Angles and Lengths inclosing the *Stockin* are truly laid down.

But

But if the Extremity of the last Line does not coincide with the Extremity of the last Off-set laid off from the Station-Line $\odot 3$, $\odot 4$, both denoting the North-West Corner of the *Stockin*, the Lines and Angles, designed to inclose the same *Stockin*, are not truly laid down, and therefore must be corrected before I proceed.

Next, I lay the Protractor $\odot 9$, and, having laid down the Angles $\odot 8$, $\odot 9$, $\odot 10$, I prick off the several Off-sets, marking them as the Field-Book directs, where the Lines of Partition within come up to the Hedge.

Having drawn the Chain-Link from $\odot 10$, and set off the last Off-set therefrom 20 Links, I find the Extremity of that Off-set to coincide with the Mark I drew cross the Fence at the 2d Off-set from $\odot 3$, which proves the Work to be truly laid down.

The Out-Lines round the *Orchard, Garden, Yard, &c.* being drawn, the external Angles about the Buildings may be measured with a Bevel; or else with the Chain only (as directed in the Use of the Chain;) which, together with the Remarks on the Outsides, will be an easy Direction for drawing the several Boundaries within those Lines.

Having finished the Ground-Plot about the Buildings, I find the next Station in my Field-Book, marked $\odot 8$. *ret.* therefore I return to $\odot 8$, in my Draught, and lay down that Angle by the Line immediately preceding that Station, *viz.* $\odot 7$, $\odot 8$, and proceed to $\odot 11$, laying down the several Occurrences as noted in the Field-Book.

The Rules I observe in these Cases are to number with Black-Lead all the Stations I have already laid down in my Draught, and to express those Numbers successively one after another, in a Piece of Waste Paper.

If

If the Number of the present Station doth not immediately succeed that of the last, but is greater by an Unit than any of the Numbers in the waste Paper ; then I lay down the Angle of the present Station with the Line I measured immediately before I came to it, and number it as in the Field-Book.

But, if the Number of the present Station is greater than any in the waste Paper by more than an Unit, there hath been some Omission in the waste Paper, which must be rectified.

If I come to a Station, whose Number is already entered in the waste Paper, then I return to that Station in my Draught, and there lay down that Angle with that Line measured immediately before I came to this Station the first Time.

Thus, observing these Directions, may the Plot be laid down without any Burden at all to the Memory ; and, if it was surveyed by one Man, it may be plotted by another, provided the Person who surveyed it, observed these Rules, and any Method of keeping a Field-Book, that lays a Burden on the Memory, is imperfect, and not fit for Practice.

The remaining Part of the Work is reserved for the Exercise of the Reader : The Plan thereof was here laid down by a Scale of $\frac{1}{4}$ of an Inch : I sometimes lay down the Plot of each Field by a Scale of half an Inch or larger, if the Plot will lie on one Sheet of Paper, and cast up the Content of each separately by that Scale ; and, for this Purpose, the Sheets, with Meridians ready printed thereon, are very serviceable. Afterwards I lay down the whole Plan together by a Scale of a Quarter of an Inch or less, entering the Content of each Field, as cast up by the large Scale in the Middle thereof.

S E C T. III.

Observations on measuring Land in Common-Fields.

WHEN ploughed Lands in Common-Fields are measured by the Chain, 'tis usual to measure the Length down the Ridge of the Land, and to take the Breadth at the Top of the Land, about the Middle, and at the Bottom; and adding these three Numbers together to take the third Part of the Sum for the mean Breadth: but 'tis not advisable to take the Breadth very near the Lands Ends, because the Turning of the Plough generally makes it considerably narrower or wider; and, if in measuring down the Land you find the Breadth is not nearly equal, 'tis best to measure cross the Land oftener, as at every 3 or 4 Chains Length, and, adding the several Breadths together, divide that Sum by the Number of Breadths, for the equated Breadth: And, for this Practice, half the four Pole Chain is most convenient, remembering either to set them down as whole Chains, or to make them so, when you cast up the Content.

The several Furlongs, in common arable Fields, may be accounted as so many particular Inclosures, and measured after the same Manner, by setting up Marks at the Extremities of the Furlong, and measuring the Angles by the Theodolite, as before directed; and, as you pass along the Station-Lines, you may from thence take Off-sets to each Man's particular Lands; and, against that Off-set, write the Name of the Owner or Tenant: And when you plot that Furlong, you may, by those Directions in your Field-Book (if you will take the Pains, which is not a little) express each particular Land in your Draught

Draught, with its Buttings and Boundings (but the Buttings and Boundings of Land in Common-Fields is necessarily expressed in all Cases): An Example of this is needless, only it may be added, that, in the Survey of a large Common-Field, 'tis safer to divide it into Parcels, as separate Fields, keeping good Marks at the Stations, than to venture the Closing of the Plot, by going round it all at once, and dividing it into Parcels afterwards.

S E C T IV.

Of Reducing Plots.

THE Plot of a Manor or Lordship consisting of several hundred Acres lying together, being laid down by a Scale of a Quarter of an Inch or less, may yet be larger than is desired, and therefore must be reduced into a lesser Compass. Now for the Performance of this Work there are several Instruments, as a long Scale made with a Center-hole at one third Part thereof; so that two third Parts may be numbered one Way with equal Parts from the Center hole to the End; and the other third Part numbered the other Way with the same Number of equal Parts, though less according to what Proportion you please: But to pass by this, and several others, I shall only give an Instance of the *Parallelogram*, which is commonly made of six wooden Rulers joined together, and supported by Brass Feet, with Holes in the Rulers for setting the Instrument to certain Proportions.

But sometimes these Instruments are made of Brass, and so as they may be set to any given Proportion whatever, by the Help of sliding Centers, that are moved along certain Lines calculated for that Purpose, and divided on the Sides of the *Parallelogram*; so that a Plot may be reduced

with the utmost Exactness according to any given Ratio, in respect of the former, either in Proportion, as the Length of the Sides of the foul Plot shall be to the fair one, or else as the Area of the one to the Area of the other. By this Instrument Curves are as well reduced as Right-Lines, which by any other Instrument is exceeding difficult, if not impossible to be done.

The Parallelogram being fixed upon a very smooth and even Table, and the foul Plot and fair Paper fastened thereon, one over-against the other; set the Parallelogram to what Proportion you would have your reduced Plot be of, in respect of the former, then bring the Point of the Tracer to one of the outmost Angles of the foul Plot, and put in the Point which is to draw in its Place, letting it rest on the fair Paper: Then move the Tracer with a gentle, equal Motion over all the Lines of the foul Plot; so shall the Motion thereof occasion the Drawing-Point to draw upon the clean Paper or Parchment the true and exact Figure of the former Plot, tho' of another Bigness, according to what Proportion you set your Instrument; which will better appear by seeing the Instrument once used, than Words can possibly explain.

When you have gone round the Lines that inclose one Field, you may take out the Drawing-Point and bring the Tracer to any other Point on the foul Plot; then put the Drawing-Point in its Place again, and proceed on with your Work.

Note, This Instrument is useful, not only for this Purpose, but also for Copying any small Print, &c. in Miniature.; but for reducing great Plots of Land, it should be made of a larger Size than is commonly used for other Purposes.

Schol. The Parallelogram is a pretty contrived Instrument; but whether for the Purpose of a Surveyor, the *Proportional Compasses* will not do as well

well or better, must be left to the Decision of those who have experienced both. The Compasses consist of two Legs of equal Length, having a steel Point at each End; the Center which joins the Legs together is moveable up and down the Middle, by which Contrivance the Instrument may be set in any given Proportion. When the Center is exactly in the Middle, the Distance betwixt the Points at each End will be the same, whatever Extent they are opened to; if the Center be moved a little higher up, the Extent betwixt the upper Points will be less than that betwixt the lower ones, and that always in the same Proportion whilst the Center remains in the same Place. There are usually Divisions cut upon one of the Legs for setting the Center according to any given Proportion; but lest these Divisions be faulty, you may correct them thus: Let the Proportion assigned be as 2 to 1; having set the Center to the Number 2, open the Legs, and by the widest End take some Number off a Scale of equal Parts, suppose the Scale 20; then if the other End will reach to the same Number upon the Scale 40, the Center is rightly placed, otherwise it must be moved a little as you see occasion.

To reduce Plots by this Instrument.

For Example, Let it be required to reduce a Plot to a Scale of half the Bigness. 1. Draw parallel and equidistant Right-Lines along the Plot to be reduced; this Distance may be $1\frac{1}{2}$ Inch or 2 Inches; cross these again at Right-Angles with other Lines drawn exactly at the same Distance; then will the whole Plot be reduced into Squares all of equal Bigness. After the same Manner reduce the Paper or Parchment on which your new Plot is to be drawn into Squares, whose Sides are exactly half the Length of the former. Then the proportional Compasses being set in the same Proportion with the Sides of

the Squares on the two Plots, you will be able readily and expeditiously with a little Practice to reduce one Plot into the other.

S E C T. V.

Directions for Beautifying and Adorning of Plots.

HAVING reduced the Plan of the Lordship, Manor, &c. to the intended Bigness, 'tis necessary to draw imaginary Lines, both vertical and horizontal, denoted by Letters at the Top and Bottom, and also on the Sides; to be referred to by the Table of References, for the ready finding of any Field or Parcel of Land therein contained; such as you will find in the new Maps of *London*, &c.

The *North* Part of the Plot is always supposed to be placed upwards, and the *East* to be on the right Hand.

The Representation of Hedges ought to be laid down on the same Side of the Fences that they are in the Land, and to be broke off where there are to be Representations of Gates

The Out-borders of the Plot, at least such as border next to the Demesnes, ought to be filled with the adjacent Hedges, and the Tenants or Owners Names of the Grounds.

If you describe all Rivers, Highways, Windmills, large single Trees, Gates, Stiles, &c. that fall within your Plot, it will add to the Beauty thereof.

The Ground-Plot of Buildings ought in all Cases to be expressed by the same Scale that the rest of the Plot was laid down by, and to be taken Notice of in the Table of References; but never go about to draw the Representation of an House or Barn in the midst

midst of the Plot, so big as will cover an Acre or two of Land.

But if you would express a Gentleman's Seat, or Manor-house, 'tis best done in some Corner of the Draught, or in a Plan by itself, annexed to that of the Estate to which it belongs. And the House must be drawn in Perspective (as you will be shewed hereafter) and if the Gardens, Walks and Avenues to the House are expressed, it must be in the same Manner; and where there are Trees, they must be shadowed on the light Side.

If you will take the Pains, you may, in one of the upper Corners of the Plan, draw the Mansion-House, &c. in the other the Lord's Coat of Arms, with Mantle, Helm, Crest, and Supporters, or in a Compartment, blazoning the Coat in its true Colours: In one of the Corners at the Bottom, you may describe a Circle, with the 32 Points of the Mariners Compass, according to the Situation of the Ground, with a *Flower-de-luce* at the *North* Part thereof, always allowing for the Variation of the Needle: And, in the other Corner, make a Scale equal to that by which the Plot was laid down, adorning it with Compasses, Squares, Ovals, &c.

Having wrote the Name and Content of each Close about the Middle thereof, you may, about the Bounds of each Field or Inclosure, with a small Pencil, and some transparent Colour, neatly go over the black Lines; so shall you have a transparent Stroke or Margin on either Side of your black Lines, which, being shadowed, will add a great Lustre and Beauty to the Plot.

If you would have your Fields all coloured, it will not be amiss to pounce over the Paper or Parchment with some Stanish Grain and burnt Allom, and a double Quantity of Rosin, finely searced and lightly pumised, to preserve the Paper from being pierced through with the Colours; or wet it over

with Allom-Water, which will add to the Lustre of the Colours.

Then lay on the Colours in Manner following, being first ground, and bound with Gum-Water very thin and bodiless : *Arable* for Corn, you may wash with pale Straw-Colour, made of King's Yellow and White ; for *Meadows*, take Pink and Verdigris in a light Green ; *Pasture*, in a deep Green of Pink, Azure and Smalts ; *Fenns*, a deep Green ; as also *Heaths* of Yellow and Indico ; *Trees*, a sadder Green, of White and Verdigris ; for *Mud-Walls* and *Ways*, mix White and Rust of Iron, or with brown Oker of *Spain* ; for *White Stone*, take Umber and White ; *Water* or *Glass* may be shewn with Indico and Azure or *Indian Ink* ; for *Seas*, a greenish Sky-Colour, of Indico, Azure, Smalts, White and Verdigris.

Having washed your Pencil very clean, take a small Quantity of the Colour, and on the Inside of the Bounding-Line draw the Colour along, of an equal Breadth, as near as you can, broader or narrower as the Field is in Bigness ; and, having gone round the Field in this Manner, swill the Pencil in fair Water, and strike along the Inside of the coloured Line, bringing it down more towards the Middle of the Field ; and this will soften your Colour, and make it shew as if it lost itself by Degrees to the very Colour of the Paper : Lastly, with a Pen take some of that Colour which shadoweth the Colour you laid on the Field, and go over the black-lead Line only ; so shall your Field be finished.

In this Manner, you may make 100 Fields in one Plot, of divers Colours, observing, as near as you can, not to colour two Fields adjoining to one another of the same Colour ; and therefore it will be convenient to understand what Colours best set off one another ; and as near as you can, lay the Inclosures

Fig: 41



tures adjoining to one another, of two such Colours, that one Shadow may serve both.

This Colouring and Adorning of Plots is rather the Painter's Work than the Surveyor's ; yet if he has Time to spare, and Patience to finish the Work, it may prove a pretty Diversion. But for the general Practice, I would recommend the Use of *Indian Ink*, which, ground very fine upon a smooth Tile, and the Hedges or Bounders of each Field shadowed therewith, will look very neat, and make the Plot resemble one done from a Copper-Plate, if rightly managed.

The Water-Colours before-mentioned you may have in Shells ready prepared (being much readier than to trouble yourself with grinding, &c.) as also the *Indian Ink*, Pencils, &c. at any of the Colour-Shops.



C H A P. VI.

The Manner of laying out or dividing Land.

S E C T. I.

Of Laying-out Lands.

P R O B L E M I.



IF any Quantity of Acres be given, to be laid out in a square Figure, annex to the Number of Acres given 5 Cyphers, which will turn the Acres into square Links; then from the Number thus increased, extract the square Root, which shall be the Side of the proposed Square.

So, if you would cut out of a Corn-Field one square Acre, add to 1 five Cyphers, and then it will be 100000, the Root of which is 3 Chains 16 Links, and something more for the Side of that Acre.

Problem. 2. If you would lay out a given Quantity of Acres in a Parallelogram, whereof one Side is given—First, turn the Acres into square Links, by adding 5 Cyphers; and divide that Number thus increased by the given Side, the Quotient will be the other Side: As if 100 Acres were to be laid out in a Parallelogram, one Side whereof shall be 20 Chains; therefore to the 100 Acres add 5 Cyphers, which

Sum

Sum divide by 20 Chains, the Length of the given Side, the Quotient will be 50 Chains for the Length of the other Side.

Problem 3. If you would lay out a Parallelogram that shall be 4, 5, 6, &c. times longer than it is broad: First, turn the given Quantity of Acres into Links, as before, which Sum divide by the Number given, for the Proportion between the Length and Breadth, as 4, 5, 6, &c. the Root of the Quotient will shew the shortest Side of such a Parallelogram: As if it was required to lay out 100 Acres in a Parallelogram that shall be 5 Times as long as broad; first, to the 100 Acres add 5 Cyphers, and it makes 10000000; which Sum divide by 5, the Quotient is 2000000, the nearest Root of which is 14 Chains 14 Links, and that shall be the shortest Side of such a Parallelogram; and, by a multiplying that 14 Chains 14 Links, by 5, shews the longest Side thereof to be 70 Chains 70 Links.

Problem 4. If you would make a Triangle that shall contain any Number of Acres, being confined to a certain Base: First, double the given Number of Acres, to which annex 5 Cyphers, and divide that Sum by the Base; the Quotient will be the Length of the Perpendicular: As if the Base given be 40 Chains, upon which you are to make a Triangle that shall contain 100 Acres; first, double the Number of Acres, and, annexing 5 Cyphers thereto, divide it by 40 Chains, the limited Base; so shall the Quotient be 50 Chains, for the Height of the Perpendicular, which set on any Part of the Base; then you may, from the Extremities of the Base, draw the other two Sides, which shall form the Triangle required.

So if, when you are laying out a new Piece of Land of any given Content, although you meet in your Way with 100 Lines and Angles, yet you may, by making a Triangle to the first Station you began at, cut off any Quantity required.

S E C T. II.

Of Dividing Lands.

E X A M P L E I.

Suppose it was required to divide *Fig. 42.* whose Content is 10 *A.* 3 *R.* 22 *P.* into 2 equal Parts, by a Line drawn parallel to *a b*.

First, the Acres, Roods, and Poles must be reduced into square Links, which may be done thus:

If the Roods are $\left\{ \begin{smallmatrix} 1 \\ 2 \\ 3 \end{smallmatrix} \right\}$ add $\left\{ \begin{smallmatrix} 40 \\ 80 \\ 120 \end{smallmatrix} \right\}$ to the Poles,

and to the Sum annex 4 Cyphers; divide this last by 16, and write the Quotient Figures, if they be 5, after the Acres. But if the Quotient

Figures are but $\left\{ \begin{smallmatrix} 4 \\ 3 \end{smallmatrix} \right\}$ write $\left\{ \begin{smallmatrix} 1 \text{ Cypher} \\ 2 \text{ Cyphers} \end{smallmatrix} \right\}$

after the Acres, and then the Quotient Figures; so will you have the square Links required.

Therefore 10 *A.* 3 *R.* 22 *P.* reduced into square Links, will stand thus:

$$\left\{ \begin{array}{r} 22 \\ 120 \\ \hline 16 \overline{) 142.0000} (88750 \\ \text{Square Links—} 1088750 \end{array} \right\}$$

Having reduced the Acres, &c. into square Links, they make 1088750, the Half of which is 544375; next draw a Line by Guess parallel to *a b*, as the Line *c d*, and then cast up the Content of the Figure *adcb*, which suppose 494375 square Links; this is less than 544375 by 50000 square Links, which shews that the Partition-Line must be set forwarder from *b a*.

Now, in order to know how much *c d* must be set forwarder, I divide the Excess 50000 square Links by

by the Length of the Line cd , 953 Links, and it quotes 52 Links; therefore from c I set off 52 Links, and draw the Line fe parallel to ba , and it will be sufficiently near the Partition Line.

This is performed by the second Problem of the last Section; but, if those Parts of the Boundaries $cfde$ be not nearly parallel, then 'tis best to draw a Triangle to cd , instead of the Parallelogram $cfde$.

But if cd had cut off the Quantity $adcb$, greater than that required, then the Partition-Line had been more towards ab , whose Distance might be found as before.

Example 2. Suppose it was required to cut off from *Fig. 43.* six Acres towards gf , by a Line drawn from a given Point in the Boundary ga , at a .

First, reduce the given Quantity, 6 Acres, into square Links, and they will be 600000; and then draw the Line ab , by Guess, from the given Point a , and cast up the Content of $gabf$, which amounts to 431680 square Links, which is too little.

Next draw the Line ae , from the Point a , forming the Triangle abe , whose Content is 235600, which added to the Part $gabf$, amounts to 667280, which is more than the given Quantity 600000, by 67280 square Links; therefore the Partition-Line passes between e and b .

Now divide the Excess 67280, by 380, half the Length of the Perpendicular ac , in Links; the Quotient is 77 Links, which set off from o towards b , and draw ad , which is the true Line of Partition.

Example 3. Suppose *Fig. 44.* was to be divided equally among three Tenants, in such a Manner that the dividing Lines may pass through the Pond o , in the Middle of the Field, so that each Tenant may have the Benefit of the Water.

First, Reduce the whole Figure into square Links, and it will be found to contain 1477410; then each
Tenant

Tenant must have one third Part thereof, *viz.* 492470 square Links.

From *o* to any two Angles, as *a* and *b*, draw the Lines *oa*, *ob*, forming the Triangle *ao b*; which being cast up, amounts to 291984 square Links, which is too little.

To the next Angle *f*, draw *of*, forming the Triangle *aof*, which being cast up, amounts to 231000 square Links, which, added to the Triangle *ao b*, gives 522984, which exceeds the Quantity required by 30514 square Links.

Divide the Excess 30514 by 347, half the Length of the Perpendicular *og*, and lay the Quotient 87, from *f* to *b*, and so shall *boba* be one third Part of *abcdef*.

Next draw the Line *oe* to the next Angle *e*, and cast up the Content of *oef*, amounting to 256410 square Links; to which add the Triangle *bof* 30514 square Links, the Sum is 286924, which is too little.

Therefore draw *od* to the next Angle *d*, and cast up the Content of *oed*, 265500 square Links, to which add *boef* 286924, their Sum is 552424 square Links; which is more than the third Part of *abcdef*, by 59954 square Links.

Divide the Excess 59954 by 295, half the Length of the Perpendicular *oi*, and lay the Quotient 203 Links from *d* to *k*, and draw *ok*; so shall *Fig. 44.* be divided into 3 equal Parts, by the Trapezias *bako*, *bfeiko*, and *kdcbo*, as was required; and the Pond *o*, laid out to each Tenant apart.

These three Examples express all the Variety that most commonly happens in Practice; for either the Partition-Line is required to be parallel to some other Line assigned; or to pass through some given Point in the Fence; or to pass through a Point assigned in the Land.

If

If a Piece of Common was to be divided amongst several Tenants, in Proportion to the Rent which each pays for his Farm: The Numbers being reduced to the lowest Denomination (except you express the Parts of Acres and Pounds by Decimals, which is better) the Rule is :

As the Sum total of all the Tenants Rent is to the whole Number of Acres in the Piece of Land contained; so is each particular Tenant's Rent to the Number of Acres to be laid out for his Part. This is very plain, and needs no Example.

So if a Piece of Common was to be inclosed, and divided amongst several Tenants, according to the Number of Beast-Gates which each Tenant hath in the Common, it is to be performed by the same Rule.

There is no Need of Direction how to make the Lines on the Land in the same Position as on the Paper-Plot, by carrying the Chain in a strait Line from Point to Point, on the Land itself, as divided on the Paper: Only take Notice, that the larger the Scale is, by which the Plot is laid down on the Paper, the exacter will the odd Links of each Line be estimated by the Scale, in order to transfer those Lines to the Land.

But if you are to divide a Wood, or very hilly Ground, so that you cannot see the Marks from Side to Side, do thus:

Be sure to keep good Marks at every Station, as you measure round it, that you may find the Hole at each, in which the Staff stood; then having plotted the Wood, and divided it on the Paper-Plot, in such Manner as desired; plant the Center of the Theodolite directly over that Point in the Station-Line on the Land where the dividing Line cuts it on the Paper-Plot, and bring the Index to 360; or set it in the same Position as it was at the forward Station when you measured that Angle, turning about
the

the Instrument, till the Hair in the Telescope cuts the last Mark; so that the Telescope be set exactly in the Direction of the present Station-Line, where the dividing Line cuts, and there screw the Instrument fast: Then measure, with your Protractor on the Paper-Plot, the Angle which the dividing Line makes with the present Station-Line; and turn about the Index on the Limb to the same Angle, so shall the Telescope be set in the Direction of the dividing Line; then, by looking through the Telescope, you may cause Staffs to be set up in the same Direction: And thus proceed in a strait Line, till you are far enough in the Wood, or quite through, if it be divided by one Line; but, if by two Lines, you must continue them till they meet one another, as in the Paper-Plot.

The same Thing may be performed by the plain Table, or the Chain only; but those Instruments are not so convenient to measure a Wood, or hilly Ground, as the Theodolite.

S E C T. III.

How to reduce Customary into Statute Measure.

IF you would change Customary into Statute Measure, & *è contra*, the Rule is: *As the Square of one Sort of Measure is to the Square of the other; so is the Area of the one to the Area of the other.*

In some Parts of *England*, they account 18, in some 20, 22, &c. Feet to a Pole or Perch, and 160 such Perches to make an Acre, which is called *customary Measure*; whereas our true Measure of Land, by Act of Parliament, is but 160 Perches to an Acre, accounting 16 Feet and an half to the Perch.

So

So if a Field measured by a Perch of 18 Feet, accounting 160 such Perches to the Acre, contains 100 Acres; how many Acres shall the same Field contain by the Statute Perch of $16\frac{1}{2}$ Feet? Say, As the Square of $16\frac{1}{2}$ Feet, (*viz.*) 272.25, is to 100 Acres, so is the Square of 18 Feet (*viz.* 324) to $119\frac{8}{1000}$ of a Statute Acre. See the Operation at large.

16.5	
16.5	18
<hr style="width: 50px; border: 0.5px solid black;"/>	<hr style="width: 50px; border: 0.5px solid black;"/>
825	18
990	<hr style="width: 50px; border: 0.5px solid black;"/>
165	144
<hr style="width: 50px; border: 0.5px solid black;"/>	<hr style="width: 50px; border: 0.5px solid black;"/>
272.25	18
272.25 : 100 :: 324 :	

272.25)32400.00(119.008 Acres.

$$\begin{array}{r} 51750 \\ 245250 \\ 0225 \end{array}$$



C H A P. VII.

General Observations on the Method of Surveying and Plotting of Roads, Rivers, &c. With short Hints how to make the Draught of a County, or Ground-Plot of a City, &c.



IN this seventh Chapter I have added general Directions for Measuring of Roads, &c. omitting particular Forms of Charts, which would take up more Room than can be spared in this small Tract ; and indeed, if the several Varieties that occur in these large and spacious Works were inserted, it would swell to a large Volume : But since the Surveyor's Judgment in contriving and carrying on his Work must be his best Guide ; these few Observations may serve as Memorandums of the most necessary Things in Practice ; which, together with other Rules before laid down in this Tract, may perhaps be a sufficient Instruction for the Performance of any Thing of this Nature.

S E C T.

S E C T. I.

General Directions for making a Draught of the Roads lying through any Country, &c.

INstruments fittest for this Purpose, are, 1. The *Theodolite* as before described; the Angles which each Station-Line on the Road makes with the Meridian, being observed by the Limb in the same Manner, as before shewed, and the Bearings of the several Remarks from thence by the Needle. 2. The *Wheel*, or *Way-wisper* to measure the Length of the Lines, by driving the Wheel on the Road before you; so shall the Hands on the upper Part of the Instrument shew how many *Miles*, *Furlongs*, and *Poles*, you go at one Time from any Station. 3. The *Protractor*, as before described: A neat *diagonal Scale* of Brass, and a good *Pair of Compasses*. Or, you may have a *Beam Compass*, with such a Scale on the Beam as shall be agreeable to the Largeness of your Plot; and thereby you may lay down the Length of your Lines very expeditiously, by setting one Foot of the Compasses at one End of the Line, and moving the Socket on the Beam to one of the equal Divisions near the other End of the Line you are about to lay down, representing Chains or Furlongs; and then you may bring the Point of the Compass which stands perpendicular on the Paper to the Parts of that equal Division, representing Links or Poles by the Help of a small Screw; there being Divisions on the Edge of the Socket sliding close on the Beam according to *Nonus's Projection*; so that the Links of a Chain or Poles of a Furlong are estimated in the same Manner as the Minutes of a Degree on the Limb of the *Theodolite*. In these large Plans, where the Distances of Places are determined by the Intersection of Right Lines from your Stations,

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tions, those stationary Distances ought to be laid down as accurately as may be; for, where a Mile is laid down in the Compass of an Inch, a Prick of the Compasses is considerable.

In order therefore to make a Draught of the principal Roads that lie through any County, &c. First, begin at some noted Market-Town, or rather at the County-Town; placing the Theodolite at some remarkable Church, &c. then having a Field-Book with large Margins to enter the Remarks, and the middle Column representing the Station-Lines divided into three Parts; at the Head of which write *M.* for Miles, *F.* for Furlongs, and *P.* for Poles.

When you begin your Journey, at the Top of the Field-Book write the Name of the Place where you begin your Work, and make \odot 1 in the Field-Book to represent the first Station: Send some Person forwards on the Road, with a white Flag in his Hand, as far as you can see; and then by some known Sign cause him to stand; then bring the Index to 360 on the Limb, and turn the Instrument into the Direction of the Meridian, and there fix it; then direct the Telescope to the Person on the Road, and note the Degrees cut on the Limb for the Bearing of the first Station-Line.

Put the Hands to the Beginnings of the Numbers on the Plate, and bring the Wheel to the Station; then cause one to drive it from the Place where your Instrument stood, towards the Man on the Road, till you see some remarkable Object on either Side thereof; there let him stop and direct the Telescope to that Object, and note the Degrees which the Needle points to in the Box, and at what Distance the Instrument is planted from the last Station, together with the Name of the Object to which the Telescope was directed.

Having entered this in the Field-Book, go on with the Wheel till you see something else remarkable on
either

either Side of the Road; there stop and take a Bearing; and in this Manner proceed till you come up to the Man at the second Station, observing as you go along on the Road from Station to Station: *First*, what *By-Lanes* or *Roads* you meet with in your Way, whether they be to the right Hand or to the Left, and to what Places they go; how they incline, whether forwards or backwards, or whether they be at right Angles with the Road you are measuring, and note it down in the Field-Book with two Lines thus = on the right or left Side of the Station-Line: That is, if the Road or Lane be on the right Hand, then place it on the right Hand; but if the Road be on the left Hand, then place it on the Left: If the Road doth incline forwards, then mark it on either Side of the Lane or Road thus \angle : If the Road or Lane incline backwards, then mark it thus \nearrow : If it be at right Angles with the Road you measure, then mark it down thus \perp : If another Road crosses that you are upon, note it thus \times : Likewise set down at what Distance from your Stations the Lanes or Roads turn out from the Road you measure, viz. at so many Furlongs, &c. a Road to the Right or Left of such a Place.

Likewise, when you pass over any *Bridge*, note it in the Field-Book, with the Distance from the last Station; as also the Name of the Water that runs under it, and from whence it hath its Rise, and where it empties itself: The same must be observed when you pass over any *Ford* or *Rill*.

Note down also, when you ascend an *Hill*, and when you come to the Top thereof, and when you descend the same, and come to the Bottom thereof.

When you pass through any *Town* or *Village*, note at how many Miles, Furlongs, and Poles, you enter the same; and at how many Miles, &c. you leave it, and whether the Houses be close, or scattering, or on the right or left Side of the Road, or

on both Sides of it; also write down the right Name thereof; and, if a *Market-Town*, take Notice on what Day the *Fairs* or *Market* are kept, and by what Officers the Town is governed.

Note down also the *Mills* that are on the Road, whether *Water-mills*, or *Wind-mills*, and the Distance from your last Station. If there be any *lone Churches* on the Road, note them down by their Names, and whether they be Towers or Spires, with their Distance from your last Station.

In your measuring along the Road, if you see any *Churches*, *Mansion-Houses*, *Beacons*, *Wind-mills*, *Towns*, *Villages*, or any other Thing remarkable, you must take a Bearing to each, noting down in your Field-book the Name of the Place, and how it does bear, and at what Distance from your last Station you took this Bearing.

Then in your measuring forwards, at as great a Distance as you can, take another Bearing to those Places you took last, provided you may but see them, and note the Names of the Places, and how they bear, and at what Distance from your last Station, as before.

Observing these Directions, proceed with your Work on the Road as far as you can go the first Day, entering the several Observations in as plain and fair a Manner as possible in the Field-book; and then it may be convenient to protract that Day's Observations, before you go any further.

Therefore, on the Paper or Parchment, on which you draw the foul Draught, let there be ruled Meridian-Lines all over, exactly parallel to one another; and chusing a proper Place in one of the Lines, to represent the first Station, draw an occult Line from thence, making such an Angle with the Meridian, as you observed the first Station-Line to do, when you directed the Telescope to the Man standing in the Middle of the Road.

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When you have drawn the Station-Line in its true Position, set thereon the several Distances from the last Station very exactly, at which you made any Remarks, as you find them noted in the Field-book; and make a small Prick at each, in the Station-Line: Then having made the Station-Line of its just Length, proceed to lay down the several Objects you observed on each Side the Road, in their true Situation; as suppose a Steeple that stands at a Distance from the Road, *viz.* a Mile or two; lay the Center of your Protractor on the Place at which you took the Bearing, (*Ex. gr.* so many Poles, &c. Distance from such a Station, such a Steeple did bear from you $207^{\circ} 40'$) and against the Degrees of Bearing make a Mark, and draw a Line at Length.

Then at the second Place in the Station-Line, where you observed this same Steeple to bear from you, lay the Center of your Protractor, and against the Degrees of Bearing make a Mark, and likewise draw a Line at Length; and, where this last Line of Bearing intersects the first Line of Bearing, there place the Steeple, with the Body of the Church to the East Side thereof.

All *Wind-mills*, eminent Houses, or other Remarks that are distant from the Road, you must protract, in the same Manner as you did the Church, by the Bearings, and likewise write down the Name of each; and, if you protract a *Village* that stands at a Distance from the Road, you must signify by Writing the same, that it is a Village; but, that you may know Market-towns from Villages, write the Name of the Market-town in a different kind of Letter; and if you protract a Village that is in the Road, with Houses scattering, you must place your Houses scattering on the right or left Hand of the Road, as you noted them in the Field-book.

You must protract the Road all along with two Lines parallel one to the other. If your Road hath Hedges on both Sides, then draw your Lines black; but if your Road be an open Way, then draw it with pricked Lines; you may also insert the Quality of the Ground, whether it be a *Common*, *Moor*, or *arable Land*.

If the Road pass through a *Wood*, then make little Trees on both Sides the Road, to signify the same so far as the Wood goes.

If the Road passes over an *Hill*, you must, at the Beginning where the Hill ascends, shadow very deep, and, as the Hill more and more ascends, you must shadow it lighter, till you come to the Top thereof: But if the Hill makes an Angle of above 5 or 6 Degrees, or thereabouts; and the Height be above a Furlong, you must find the horizontal Line of that Hill, and protract that; otherwise a great Error may ensue.

If there be a Village or Town on the Side of the Hill, you must shadow it likewise, so that the Houses may be seen. If the Remarks that are at a Distance from the Road stand on a Hill, make an Hill to represent the same.

If your Road pass by or through a *Park*, *Forest*, or *Chace*, write down on your Road protracted, where you entered the same, and where you left it, writing the Name thereof among the Trees.

If your Road pass over a *Ford*, draw the River quite cross the Road, to signify there is no Bridge, and write the Name of the Ford; but if there be a Bridge, then draw the River on both Sides of the Road, till it touch the parallel Lines; and write the Name both of the Bridge and of the River; likewise write on that Side of the Road that the Stream runs from you, at what Place the River empties itself; and on the other Side of the Road

Road write from whence the Water or River hath its Rise, if you can learn that of the Inhabitants.

All *Rills* you may signify by drawing a Line cross the Road; and *Brooks* may be signified by drawing two Lines cross the Road, and *Rivers* by more Lines, together with the Names; for all Rivers have Names, but Rills and Brooks often have none.

It will likewise be necessary, that you take Notice of the Quality of the Way, whether it be stony, clayey or boggy, and write it down on the Road that you have protracted: And by this Means you will have your Road very full of Remarks, and it will shew very neat and handsome.

S E C T II.

Containing general Directions for making the Plot of a River or Brook, by the beforementioned Instruments.

FIRST, when you come to the Mouth of the River, cause a Man to go and stand at the next Bend thereof; then plant your Theodolite at the Mouth of the River, letting your Needle hang directly over the Meridian-line in the Box; there fix the Instrument fast, and direct your Telescope to the Man that stands at the next Bending of the River, and note down the Angle in your Field-book, as you did in the Road.

Then cause the Man that drives the Wheel to measure between your first Station, and the Man at the next Bending; and note that down also in your Field-book, under Miles, Furlongs, and Poles.

Then bring your Instrument to the Man at the first Bending of the River, and cause that Man to go forwards, till he finds another Bending; there let

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him stand; and, placing your Instrument where the Man last stood, let your Needle (as before) hang directly over the Meridian-line, and there make your Instrument fast; then direct the Telescope to the Man that stands at the next Bending of the River, and note down the Angle in your Field-book, as you did in the former: And in this manner you must proceed all along the River, to the Head thereof.

In order to take the Breadth of the River, it will be convenient to send somebody on purpose cross the River, in a Boat, (unless a Bridge or Ferry be near) and let him set up a Staff by the Brink of the River, on the further Side, to which Staff take a Bearing, from the Place of your Standing, which call the first Station; also let another Staff be set up on the same Side where you stand, and call that the second Station, to which take a Bearing also. Now measure, in as strait a Line as possible, the nearest Distance between the 1st and 2d Stations, and that Distance note in the Field-book with the Bearings.

Plant the Theodolite at the second Station, and take a Bearing to the same Mark on the further Side of the River, and note that Bearing also in the Field-book.

When you protract these Observations, lay the Center of the Protractor to $\odot 1$, and turn it about till the Diameter be parallel to the Meridians on the Paper; then against the Degrees of Bearing from $\odot 1$, to the Mark on the further Side of the River, and also to $\odot 2$, close to the Limb of the Protractor make two Marks, through which, from $\odot 1$, draw two Lines at Length.

Set off the Distance between the two Stations on the 2d Line, and make it $\odot 2$, to which Mark lay the Protractor as before, and against the Degrees of Bearing observed at this 2d \odot , to the Mark on the further Side of the River make a Mark, through which draw a Line at Length; then will this Line intersect

intersect the first Line drawn at your first Station, and the Point of Intersection will shew the Breadth of the River.

In the same Manner are the Distances of the Churches, &c. from your Stations on the Road determined.

If there be a Ferry over the River, you must draw the River to its true Breadth, and make a pricked Line cross the River to represent the Passage of the Ferry-Boat ; and note on the Side of the River the Name of the Ferry.

In measuring on by the River, observe what *Bridges* you pass by, and at what Distance from your last Station ; also whether they be of Wood or Stone, and by what Name they are called ; also take Notice of all *Corn-Mills*, *Paper-Mills*, &c. and note them in the Field-Book, in the Column of Remarks, with their Distance from the Mouth of the River, and your last Station.

Likewise take Notice of all the *Sluices* (if there be never so many) that are on the River, and of all the *Locks* and *Flood-gates* as you pass along, with their Names, if they have any ; also if there be any *Cut* or *Canal* from the River that you are measuring, note where it goes out of the River, and where it comes in again, and for what End it was so cut : Also where any *Brook* or *River* enters into that you are measuring, note down the Place, and the Name of the River that comes in ; and also take an Account of those Places of the River that are *fordable*, and note them down in your Field-Book : And in all these Cases express the Distance of each Remark from your last Station, as also their Distance from the Mouth of the River.

You must also note in your Field-Book all the *Towns* this River runs through, or by, with the Towns Names, and the Distance from your last Station and the Mouth of the River.

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You must also take an Account of all the *Churches* that are on each Side the River within your View, by taking a Bearing to them at two several Places, as you did on the Road ; and note them down in the Field-Book, with the Distance of the Place from your last Station, where you took the Bearing to the Steeple both Times ; by this Means you will come to know how far each Church is distant from the River : The same you must do by all the *Windmills, Great Houses, &c.* noting their Names and Places of Situation in the Column of Remarks in the Field-Book.

When you have thus measured your main River, begin to measure the several *Branches* thereof ; for there are but few Rivers but have smaller Rivers running into them, and all those small Rivers ought to be done with the same Exactness as the great ones.

Note, Every Bending of all the Rivers that are navigable must be taken exactly ; but for other small Creeks there is no great Need ; for you will find such small Brooks to have a Bend at every two or three Poles, nay sometimes less, therefore they are to be taken thus :

Take your Sights as far as you can conveniently, till you find the Brook to have a considerable Bending ; and, if your Scale will permit, you may take Off-sets to represent the small Turnings and Windings thereof, as in *Fig. 41* : But, in measuring a small Brook, if your Scale is to be a Mile or two in an Inch, then these small Turnings and Windings cannot be described in the Map.

The Manner of protracting these Observations is the same with the Roads, except the Off sets from the Station-Line to the Brink of the River, and its Breadth, which are particularly to be regarded.

§ E C T.

S E C T. III.

General Directions for making a Map of a County, &c.

F I R S T, from the County-Town, or other Market-Town, where you began your Work, lay down the principal *Roads* throughout the *County*, and protract them truly, as you observed them in your Survey, inserting the *Towns*, *Villages*, *great Houses*, *Cross-Ways*, &c. according to their true Situation, taken at two Stations, as you went on the Road ; so will you (if Care be taken) have the true horizontal Distance of all those Places within Sight of the Roads, from the Road itself, or from one another.

Secondly, Lay down the *chief Rivers* that run through the County ; so will you have the Situation of several more Towns, and other Remarks, as observed in your Survey of that River ; and, when the main Rivers are done, all the Branches must be protracted with the like Exactness ; for the main Rivers and Branches being exactly done, will be a great Ornament to a County Map.

Thirdly, If the County borders upon the Sea, first protract the *Sea-Coast* exactly ; and then take a Survey of and plot all *Rocks*, *Sands*, or other Obstacles that lie at the Entrance of any River, Harbour, Bay or Road, upon the Coast of that County, by going out in a Boat to such Sands or Rocks that make the Entrance difficult ; and, at every considerable Bend of the Sands, take, with a Sea Compass, the Bearing thereof, to two known Marks upon the Shore : And, having so gone round all the Sands and Rocks, you may, upon the Plot before taken of the Coast, draw Lines, which shall intersect each other

other at every considerable Point of the Sands ; whereby you may give good Directions either for the laying of *Buoys*, or making Marks upon the Shore, for the Direction of Shipping ; and the best Time to do this, is at low Water, in Spring Tides.

Fourthly, Having truly protracted the principal Roads, Rivers, &c. with the several Remarks observed from thence, you'll find most of the remarkable Places in the County laid down : But, in order to compleat the Work, look upon some old Map of the County, and contrive three or four Market-Towns, or other Towns, to measure thro', that you have not yet laid down, and from thence to other Towns or Villages ; and so do till you have measured most or all the Roads that lead from Market-Town to Market-Town, taking all the Remarks you can as you go along ; and if you find any Thing remarkable in the old Map, that you have not yet taken Notice of, you may go and survey it. And thus, by Degrees, you may so finish a County, that you need not so much as leave out one Gentleman's House ; for scarce will any Thing remarkable escape coming into your View, either from the Roads, Rivers, or Sea-Coast.

Fifthly, When you are in a Town, place your Instrument, if you can, upon the Steeple, and from thence take the horizontal Angles to the most remarkable Objects within your View ; take the Bearings of these a second Time from some other eminent Place, and measure the Distance between these two Stations. *Note*, All Churches are to be laid down according to their horizontal Distance one from the other : Therefore, if the Road between them be over Hills of a considerable Height, the hypothenuſal Lines on the Road must be reduced to horizontal.

Sixthly,

Sixtly, All Parks and Forests must be truly laid down in the Map, as to their true Bounds and Situation; and also all remarkable Lakes of Water: You are likewise to describe the Quality of the County, whether it be hilly or woody, placing the Hills and Woods in their true Situations.

Lastly, Take the true Latitude in three or four Places in the County; which put down on the Edge of your Map accordingly.

S E C T. IV.

General Directions for taking the Ground-Plot of a City or other Town.

TH E Performance of this Work is very laborious, and you must be careful to keep the Field-Book in a plain and regular Manner, otherwise the Multitude of Observations and Off-sets will be apt to breed Confusion; but if Care be taken therein, you'll find the Work not very hard to be done: One that understands the fifth Chapter will make no Difficulty of this Section, for the several Streets, Lanes, &c. in a City are surveyed and protracted in the same Manner as the Lane, *Fig. 41.* The several Off-sets to the Houses, Churches, &c. all along the Sides of the Street being taken from the main Station-Line, running through the Middle thereof, in such Sort as the Off-sets are taken from the Station-Line to the Hedges, Gates, &c. on the Sides of the Lane.

The Instruments for this Purpose, are, 1. The *Theodolite* as before described, to measure the several Angles made by your Station-Lines, as they incline out of one Street into another; and in this Case work with the Limb only, but never trust to the Needle; for (besides the Danger of its being attracted) you
will

will find it necessary to lay down every Line by some other, given in Position in the Plot itself, rather than by the Bearings from the Meridian.

2. The *Chain*; and because the Ground-plot of the Houses, Pavements, &c. is generally laid out by Foot-measure; therefore let every Link thereof be a Foot long, and fifty of these Links will make the Chain of a sufficient Length, distinguished at every ten Links by Marks, as *Gunter's Chain* is: But, if the Content of any Part of the Plot be desired in Acres, you may reduce the Feet in any Line to Links; and for this Purpose the Table in *Chap. II.* will be a ready Assistant.

3. The *Off-set-Staff*, divided also into Feet, five of which may make it of a convenient Length, because you will have Occasion to measure many Passages, Alleys, &c. that are not wider; also at one End of the Staff you may have a Piece of about three Feet joined, like the Square of a Drawing-board; and this will be a Direction to measure the Off-sets from the Chain at Right-Angles.

4. The *Scale* (or a Beam-Compass) according to the Bigness of the Plot; the *Protractor*, the *Drawing-Pen*, &c.

First, in one of the principal Streets, as at \odot 1, in the Lane, *Fig. 41.* set up a Station-Staff, and send another forwards in the Street as far as you can see; then lay the Chain on the Ground exactly in the same Direction with the two Stations; and with the *Offset-Staff*, both to the Right and Left at Right-Angles from the Chain, measure the Off-sets as in the Lane, taking Notice at how many Links from the last Station each is laid off; and when any of those Off-sets reach any remarkable House, &c. or the Corner of a Street, Alley, or Court, enter such a Remark against the respective Off-set, in one of

of the outside Columns of the Field-Book : And in this Manner proceed to the second Station.

Set up the Theodolite at the second Station, and bring the Index to 360 on the Limb, turning the whole Instrument about till you see through the Telescope the Staff at $\odot 1$; there fix the Instrument, and then turn about the Index, directing the Telescope to another Staff sent forwards in the Street, to the further End thereof, if you can see so far ; and note in the Field-Book the Angle which the Index cuts on the Limb with the utmost Exactness : Then proceed with the Chain towards the next Station as before.

Having in this Manner gone through several of the principal high Streets, that lead through one Part of the Town, it will be convenient, as you pass along, as often as you come against any cross Street, to take a Sight down it, and note the Place or Mark to which the Telescope is directed, and also at how many Links Distance from the last Station the Instrument is planted, when you thus look into a cross Street : Note both these Places in your Field-Book, or Eye-draught, with this Mark \odot ; so that you may be sure to find the Place exactly, when you begin to take your cross Streets.

It will be convenient not only to enter your Observation in the Field-Book, but also to form a Sketch or Eye-Draught of the Work, as you go along, making Lines to imitate the same ; and draw the cross Streets, Alleys, &c. thereon, in such Manner (as near as you can guess) as you see those cross Streets to bear from the Place of your Standing in the high Streets, and write the Name of each Street between the Lines representing the same ; and this will be useful when you come to protract.

Note, Before you begin your Work, it will be necessary to walk about the Town, and chuse four or five principal Streets that lead out of one into another,

another, inclosing between them several By-Lanes, Alleys, &c. And contrive your first Station in such a Manner, that when you come round these four or five Streets, the last Station-Line may close exactly on the first Station-Point; and observe, that the fewer Angles you make in going round these Streets before you close, the better.

This is no more than surveying a Field; the main Difficulty will be to find your Stations when you come to survey the cross Streets, By-Lanes, Thoroughfares, &c. between the eminent Streets that you first went round; but you may help yourself herein, if you lay one End of the Chain at some Door, or other remarkable Place on the right Side of the Street; and draw it in a strait Line through the Station-Point to some Remark on the other Side of the Street; taking Notice at how many Links from the Right, the Chain cut the Station: You may also much help yourself herein by your Eye-Draught.

When the Station-Line leads you into a Square, you may plant the Theodolite in the Middle thereof, and from that one Station direct the Telescope to the Corners (very often there are but four, and the Sides all strait) and measure the Distances from that Station to the Corners, as in *Chap II. Sect. 4.* But if you would take Notice of particular Houses therein, or if the Sides are very irregular, then go round it: But Lanes and Alleys are laid down by Off-sets only, from the Station-Line through the Middle.

Having thus finished one Part of the Town or City, you may proceed to another till the Whole be finished; but this is a Work that will take up a great deal of Time.

The Manner of protracting this Work is the same as in the preceding Chapters, therefore particular Directions are needless; but 'tis best to protract so much as you survey in one Day, before you proceed
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with more; and, for this Purpose, a Skin of fine soft Parchment is better than Paper, unless the Paper be very fine, and pasted on Cloth or Canvas. The Ground-Plots of Churches must be very exactly taken, and laid down in the same Manner on the Draught, and shadowed very deep; the same must be observed of Houses.

Also, if you use a Protractor that will lay down Minutes, your Work will be more likely to close; for you cannot be too curious in observing and laying down the Angles, especially those in the principal Streets.



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APPENDIX

TO THE


Practical SURVEYOR.

CHAP. I.

Of LEVELLING.

SECT. I.

Of the Spirit-Level and Station-Staffs.

 HE Instrument, commonly used for *Levelling of Land*, consists of a *Brass Telescope* of about two Feet long, in the Focus of which is fixed an horizontal Hair, to cut the Object in Time of Observation: Upon the Telescope is fixed with two Screws a small *Brass Tube*, within which is a *Glass Tube* containing some *Spirits*. This Tube is hermetically sealed at each End, to prevent the Spirits running out; and the Brass Tube is filed away on the upper Side, so that the Glass Tube, and the *Bubble of Air* moving in it from End to End, may be seen. This *Bubble* is the Direction for setting the Instrument, and is occasioned by the Glass not being quite filled with Spirits. The Bore of the Tube and the Length of the Bubble should be bigger, according to the Degree of Accuracy that is required; for the bigger these are, the Friction will be less,

and the Motion more sensible. Some will move sensibly to 5 or 6 *Seconds*; but, for the Purpose of levelling Ground, they should not be made to move so quick; for, in that Case, the Instrument would be scarce manageable.

The Telescope should be fixed upon a *Brass Bar* of a convenient Strength, and of near the whole Length of the Telescope: At the farther End of this Bar there should be a short *Axis*, upon which the Telescope may have a small Motion up and down; and at the hither End there should be a *Hair Screw*, by which the Telescope may be gently raised or depressed, till the Bubble rests exactly in the Middle of (or at some particular Mark in) the Glass Tube, which is the Situation it must be always in at the Time of Observation. Under the Middle of the Brass Bar should be fixed a *Socket*, by which the whole Instrument may be readily fixed to the *three-legged Staff*, belonging to the Theodolite. Instruments for levelling should be so contrived, that the Agreement of the Hair in the Telescope, and the Bubble in the Glass Tube, might be easily examined, and (if need be) adjusted at every Observation: But, as they are not usually so made, the common Way of rectifying them will be shewed in the next Section.

Of the Station-Staffs.

Provide two *Station-Staffs*, each 10 Feet long, that may slide one by the Side of the other to 5 Feet, for easier Carriage; let them be divided into 1000 equal Parts, and numbered at every 10th Division, 10, 20, 30, 40, &c. to 100, and from 100, 110, 120, &c. to 200, and so on till you come to 1000; but every centesimal Division, as 100, 200, 300, to 1000, ought to be expressed in large Figures, that the Divisions may be more easily counted; and
you

you may have another Piece 5 Feet long, divided also into 500 Parts, to be added to the former, when there shall be Occasion.

Upon these Staffs are two *Vanes*, made to slide up and down, which will also stand against any Division on the Staff, by the Help of Springs. These Vanes may be made about 3 or 4 Inches wide, and about 10 Inches long; let the Faces of them be divided into 3 equal Spaces, by two Lines drawn lengthways; let the two extreme Spaces be painted white, and let the middle Space be divided also into 3 smaller equal Spaces, and let that in the Middle be painted white, the other 2 black, which will render them fit for all Distances.

Being thus provided with a good *Spirit-Level*, two *Station-Staffs*, a *Chain*, and two *Assistants*, you may proceed to your Work; but first it will be necessary to make a Trial whether or no your Level be well adjusted.

S E C T. II.

How to adjust the Spirit-Level.

CHOOSE some Field or Meadow that is nearly level, and set down the Instrument about the Middle thereof, and make an Hole in the Ground, under the Center of the Instrument; from which measure out, in a right Line, some convenient Length, as 20 Chains, and there leave one of your Assistants with his Station-Staff; then return to the Instrument, and measure out the same Number of Chains, viz. 20, the other Way, by the Direction of the Instrument, and last Station-Staff, as near in a Right Line as you can guess, and there leave your other Assistant with his Station-Staff; so will the Instrument and two Station-Staffs be in the same strait Line.

Then return to the Instrument, and turn the Telescope about to your first Assistant, and move the Telescope by the Hair Screw, till the Bubble rests exactly in the Middle of the Spirit-Tube; then observe where the Hair in the Telescope cuts the Staff, and direct your Assistant to move the Vane up or down, till the Hair cuts the Middle thereof, so that you may see as much of the Vane above the Hair as below it, and there give him a Sign to fix it; then direct the Telescope towards your second Assistant, and proceed in the same Manner; so are the Vanes on each Staff placed horizontally, or in a Level one with the other.

Remove the Instrument to that Assistant which is nearest the Sun, if it shines, that you may have the Advantage of its Rays upon the other Assistant's Vane, and there set down the Instrument as near the Staff as you can; then having set the Instrument horizontal, so that the Bubble rests in the Middle of the Tube; observe what Division on the Staff is then cut by the Hair in the Telescope, above or below the Middle of the Vane; for so many Divisions must the other Assistant's Vane be raised or depressed, which direct him to do accordingly.

But, because the Instrument is 40 Chains distant from the Station-Staff, you must make an Allowance for the Earth's Curvature, which by the following Table you will find to be $16\frac{6}{17}$ Parts, therefore let the Vane on the Staff be raised $16\frac{6}{17}$ Parts.

*Thus, 166 of a foot
 x 12
 1992 which call 2 inches*

A TABLE of the Earth's Curvature, calculated to the Thousandth Part of a Foot, at the End of every Chain, from 1 Chain to 40.

<i>Chains</i>	<i>Dec. Feet.</i>	<i>Chains</i>	<i>D. Feet.</i>	<i>Chains</i>	<i>D. Feet.</i>	<i>Chains</i>	<i>D. Feet.</i>
1	.000	11	.013	21	.046	31	.099
2	.000	12	.015	22	.050	32	.106
3	.001	13	.017	23	.035	33	.113
4	.002	14	.020	24	.060	34	.120
5	.003	15	.023	25	.065	35	.127
6	.004	16	.026	26	.070	36	.134
7	.005	17	.030	27	.075	37	.141
8	.007	18	.033	28	.081	38	.149
9	.008	19	.037	29	.087	39	.157
10	.010	20	.041	30	.093	40	.166

Now direct the Telescope to the Vane thus raised, and if the Hair cuts the Middle thereof, while the Bubble rests in the Middle of the Tube, the Instrument is right ; but if not, you must raise or depress the Telescope till the Hair cuts the Middle of the Vane ; and then by the Help of the Screws that fix the Spirit-Tube to the Telescope, move the Bubble till it rests in the Middle of the said Tube : So is the *Level* adjusted.

S E C T. III.

Rules to be observed in Levelling, in order to find the different Height of any two Places ; being useful for conveying Water, cutting Sluices, making Soughs, &c.

SUPPOSE it was required to know whether Water may be conveyed in Pipes or Trenches, from a Spring-Head to any assigned Place.

M 4

I. At

1. At the Head of the Spring set up one of your Station-Staffs as nearly perpendicular as you can, and leave with one (whom you may call your first Assistant) proper Directions for raising or depressing the Vane on his Staff, according to certain Signs which you (standing at your Instrument) shall give him: Also let him be provided with Pen, Ink, and Paper, to note down very carefully the Division on the Staff which the Vane shall cut, when you make a Sign that it stands in its right Position.

2. Carry your Instrument towards the assigned Place you are going to, as far as you can see, so that through the Telescope you may but see any Part of the Staff left behind, when the Instrument is set horizontal; and from that Place send your second Assistant forwards, with his Station Staff; with the same Instructions as you gave your first Assistant.

3. Set the Instrument horizontal, and direct the Telescope to your first Assistant's Staff; then bring the Bubble exactly to the Middle of the Tube, and, when it rests there, give a Sign for your Assistant to note the Parts of the Staff where the Vane rests.

4. Turn about the Telescope to your second Assistant's Staff, and by the adjusting Screw, as before, set the Bubble exact: Then direct your second Assistant to move the Vane higher or lower till you see the Hair in the Telescope cut the Middle of the Vane, (but in long Distances the Hair will almost cover the Vane; however, let it be in such Manner that as much may be above the Hair as below it, as near as you can guess) and then give him a Sign to note the Division on the Staff; and always let your Assistants note the Division cut by the upper Edge of the Vane.

5. Let your first Assistant bring his Station-Staff from the Spring-Head, and give it to the second Assistant, and let your second Assistant carry it forwards

wards towards the assigned Place you are going to, and at a convenient Place erect it perpendicular ; whilst your first Assistant carries at the Staff where your second Assistant stood before.

6. Place your Instrument between your two Assistants, somewhere about the Middle, if you can ; and first direct the Telescope to your first Assistant's Staff, and when the Telescope is levelled to one of the Divisions on the Staff, let him note that Division in an orderly Manner under the first Observation ; and let your second Assistant do the same : And in this Manner proceed over Hill and Dale, as strait forward as the Way will permit, to the appointed Place (by only repeating these Directions) tho' it be 20 Miles distant from the Spring-Head ; but in your whole Passage let this constant Rule be observed, otherwise great Errors will ensue, (*viz.*) That your first Assistant must at every Station stand between the Spring-Head and your Instrument, and your second Assistant must always stand between the Instrument and the appointed Place to which the Water is to be conveyed.

Being come to the appointed Place, let both your Assistants give in their Notes, which ought to stand in Manner and Form following.

<i>First Assistant's Notes.</i>		<i>Second Assistant's Notes.</i>	
<i>Stations.</i>	<i>Parts.</i>	<i>Stations.</i>	<i>Parts.</i>
⊙ 1	1019	⊙ 1	330
⊙ 2	512	⊙ 2	540
⊙ 3	737	⊙ 3	1337
⊙ 4	40	⊙ 4	742
⊙ 5	1495	⊙ 5	30
⊙ 6	1475	⊙ 6	32
⊙ 7	1430	⊙ 7	30
⊙ 8	1149	⊙ 8	227
<i>Sum.</i>	7857	<i>Sum.</i>	3268

These

These Notes were collected from Observations made at several Stations between the Ground at the North-Gate at *Hanover-Square*, and the Surface of the Square-Pond by the *New-River Head*, near *Islington*. The first Assistant's Notes, when added together, amount to 7857 ; the second Assistant's 3268 ; the Difference 45,86 Parts, that is almost 46 Feet ; and so much is the Pond higher than the Ground of that Part of the Square where the first Station-Staff was planted.

The following Observations were repeated in the Afternoon of the same Day, at quite different Stations, from the Pond before-mentioned to the said North-Gate of *Hanover-Square* ; and then the two Assistant's Notes stood in the following Manner :

<i>First Assistant's Notes.</i>		<i>Second Assistant's Notes.</i>	
<i>Stations.</i>	<i>Parts</i>	<i>Stations.</i>	<i>Parts.</i>
⊙ 1	290	⊙ 1	1278
⊙ 2	36	⊙ 2	1515
⊙ 3	77	⊙ 3	1395
⊙ 4	68	⊙ 4	1500
⊙ 5	58	⊙ 5	74
⊙ 6	1243	⊙ 6	38
⊙ 7	998	⊙ 7	468
⊙ 8	437	⊙ 8	774
⊙ 9	206	⊙ 9	1066
<i>Sum.</i>	3513	<i>Sum.</i>	8108

These Notes, as observed in the Afternoon, being added together, and the lesser subtracted out of the greater, the Difference is 45,95 Parts, which very nearly agrees with the former Observations ; being but $\frac{2}{100}$ of a Foot Difference, which is inconsiderable.

Note, If from the first Assistant's Staff you measure any Number of Chains towards the Place you are

are going to, suppose 10, and there set down the Instrument, and then measure ten Chains forwarder, and there place the other Station-Staff; you will have no Occasion to make any Allowance for the Curvature of the Earth, because, the Instrument being planted in the Middle of the Distance between the Station-Staffs, the Errors mutually destroy each other.

But this Measuring of the Distances with the Chain, or otherwise, is very tedious, and indeed impracticable in many Cases, unless you make a Multitude of Stations: So if the Way between the two determined Places, whose different Height you would know, lies over Hills and Dales, as *Fig. 45*, you must in that Case make four or five Stations (otherwise you will not be able to see any Part of the Staff, when the Instrument is set horizontal) which might as well be done at one Station (as in the foregoing Observations) in the following Manner.

S E C T. IV.

How to make Allowance for the Curvature of the Earth, when the Station-Staffs are planted at unequal Distances from the Instrument.

SUPPOSE the Instrument was planted on the Eminence between the two Valleys A and B. *Fig. 45*. the first Assistant with his Station-Staff, standing at C, and the second at D; and it is required to know the different Height of the Hills C and D.

First set the Instrument horizontal; and then direct the Telescope to the first Assistant's Staff at C, and by the adjusting Screw set the Bubble exact, observing where the Hair cuts the Staff; then
by

by Signs cause your Assistant to move the Vane higher or lower till the Hair cuts the Middle thereof; and then give him a Sign to note the Division cut by the upper Edge of the Vane, which suppose 104 Parts from the Ground, and you will find the Distance from the Instrument to the Staff at C to be about ten Chains *.

Then direct the Telescope to D, and, proceeding in the same Manner as before, you will find that the Hair cuts 849 Parts from the Ground: The Distance to D is about 35 Chains.

Next look into the Table of Curvature, and, against 10 Chains, you will find one Part to be deducted from the Curvature of the Earth at that Distance, so will the first Assistant's Note be made 103 Parts.

Also against 35 Chains, you will find $12\frac{7}{10}$, which being deducted out of 849, there will remain $836\frac{3}{10}$ Parts, which must be noted by the second Assistant.

Now if 103, as noted by the first Assistant, be subtracted from $836\frac{3}{10}$, as noted by the second, the Remainder will be $733\frac{3}{10}$; and so much the Hill C is higher than the Hill D: But, if you have not the Table of Curvature at hand, then you may find the Allowance that is to be made at any Distance, by this Rule.

Multiply the Square of the Distance in Chains by 31, and divide the Product by 300000.

In this Manner, making an Allowance for the Curvature of the Earth, you may send a Station-Staff forwards half a Mile, or farther, from the Instrument; and take a Sight over several Valleys at once, the horizontal Distance in this Case being only regardable.

Note, When Water is to be brought to any appointed Place, there must be an Allowance of $4\frac{1}{2}$

* *Note,* The Distance is here supposed to be found by the Theodolite, or some other Instrument fitted for this Purpose.

Inches

Inches for every Mile, more than the strait Level, for the Current of the Water ; but if the Spring-Head be much higher than the appointed Place, so that the Water will have too violent a Current, the Pipes may be laid one up and another down ; and, instead of being laid in a strait Line, the Water may be brought in a crooked or winding Way.





CHAP. II.

*Shewing the Use of the Theodolite,
in drawing Buildings, &c. in Per-
spective.*



WHEN a *Building* is to be drawn upon a *Perspective Plane* (or *Picture*) the *Representation* of the several *Objects* ought to be delineated thereon according to their *Dimensions* and different *Situations*, in such Manner that the said *Representations* may produce the same *Effects* on our *Eyes* as the *Objects* whereof they are the *Pictures*.

But without mathematical *Rules* this *Representation* cannot well be found ; for when *Objects* are drawn by only viewing or looking at them, their true *Representations* will often be missed ; whereas by the following *Method* they may always be obtained.

For all *Objects* appear such as the visual *Angle* under which they are seen ; which *Angle* is taken at the *Eye*, where the *Lines* meet that compose the *Object* ; that is to say, an *Object* seen in a great *Angle* will appear great ; and another seen in a little *Angle* will appear little ; which is the principal Thing to be observed in *Perspective*.

So the *Windows* 6, 7, 8, *Fig.* 46, must be drawn on the *Perspective Plane* of different *Dimensions* (altho' on the *Building* one of them is really as big

as

as the other) according to the Angle which the Rays from their Extremities make with the Eye at *z*.

Objects of equal Bigness appear greater or less, according to their Distance from the Beholder's Eye; so the Windows 6 and 8 are really one as big as another on the Geometrical Plane; but the Window 6, at the End of the Building, being nearer the Eye at *z*, than the Window 8 on the Front, it must be made so much larger on the Perspective Plane, as the Window 6 is nearer than that marked with 8.

Therefore, if the Angles, under which Objects appear, be given; those Objects may be drawn on the Perspective Plane (or Paper) according to their Dimensions and different Situations, in the same Form as they appear to the Beholder at any Distance.

The Figures on the Geometrical Plane (or Building) are composed either of strait Lines, or Curves: Now, to find the Representation of a strait Line, its Extremes need only be sought: And, to find the Appearance of a Curve, we need only to find the Place of several Points therein. And hence it follows, that the whole Business of Perspective consists in finding only the Place of a Point.

But these Points cannot be determined, unless by the Interfection of Right Lines. And the Reason of these Sections is, That one Line can determine nothing: Therefore it is necessary, that there be two of them, which divide themselves, (forming an Angle) for to have the Place of a Point, as will be seen in the following Example.

The Instrument referred to in this Chapter, is supposed to take horizontal and vertical Angles, both at the same Time; and the Method here laid down may serve for an Amusement, and to shew what Theory alone may do: But I fancy those who are already acquainted with the Rules of Perspective, would hardly be prevailed upon to make use of a Theodolite for this Purpose; and for those who are not, they had better make use of a *Camera Obscura*.

S E C T. I.

Let Fig. 46 represent a Building as viewed from Z, being the Place from which the Prospect is desired to be taken.

THE Instrument being planted at z , and the Staffs made to stand firm on the Ground, I set the Instrument exactly level; and with the Index at 360 , and the Quadrant at 0 Degrees, I direct the Telescope to some Part of the Building, as to o , by turning about the whole Instrument, and there screw it fast, that it stir not out of this Position, till the several Observations be finished.

The Instrument being set level, the Index, when turned round on the Limb, carries the Telescope in a Line parallel to the Horizon, as x, y : And the Quadrant, elevated or depressed, moves always in a Circle vertical thereto, as w, z .

Now with one Hand move the Index on the Limb, and with the other elevate or depress the Telescope as there shall be Occasion, till you see the cross Hairs therein cut any Point on the Building; and then note down, on a Piece of Paper, the Degrees and Minutes which the Index cuts on the Limb in one Column, and call those the horizontal Angles: Likewise note the Degrees and Minutes cut by the Quadrant in another Column, and call those the vertical Angles.

So the Telescope being directed to the Point a , the Index then cuts $7^{\circ} 25'$, and the Quadrant $19^{\circ} 30'$; and those Observations, when protracted, will give the Point a .

Likewise I make Observation of the Point b ; and then depress the Telescope to the Bottom of the Building at c , and the Index then cuts the same Angle

gle on the Limb as at *b*, and the Quadrant $8^{\circ} 30'$: But this Angle of Depression must be marked with Λ , or some such Mark to distinguish it from the Angles of Elevation, that, in protracting that Point, it may be known to be under the Horizon, or the Line $x y$.

When the Instrument is planted at a considerable Distance from the Building, the Ground there may be higher or lower than any Part of the Building: And then all the Points will be above or under the Horizon; and in such Case there will be no Occasion for this Distinction,

In the same Manner I make Observation of so many Points on the right Side of the House as is convenient; but, when the Telescope is directed to the Point *m* on the left Side, the Index cuts $340^{\circ} 40'$.

Now this Number $340^{\circ} 40'$ must not be noted for the horizontal Angle, but its Complement to 360 (*viz.*) $19^{\circ} 20'$, by subtracting $340^{\circ} 40'$, out of 360 ; but, if the Degrees be numbered by small Figures from 360 , the contrary Way, as $10, 20, 30, \&c.$ to 60 , or further, as may conveniently be done, the Numbers will increase from 360 , both to the Right and Left; and then the Index will always cut the Number denoting the horizontal Angle, in the same Manner as the Quadrant.

Having observed the Point *m*, the Index remaining at the same Angle on the Limb, I depress the Telescope to the Points, $4, 3, 2, 1$, and note the Degrees, $\&c.$ cut by the Quadrant; which, when protracted, will give the Breadth of the Faces and their Distance one from another.

Next I observe the Points of the Window *e i u*, in the left Wing of the Building; and, because these Remarks are on the left Side of the Building, therefore I note them by such Names as I call the several Points I look at (instead of the Letters *a, b, \&c.*) on the left Side of the Column of Observations,

N

viz.

viz. contrary to that Part of the Limb where the Index cuts (which remember) for when the Index is turned from 360, on the Limb towards the right Hand, the Telescope moves towards the left : And these Remarks, thus noted, must be protracted on the left Side of the vertical Line *wz*, Fig. 46.

In making these Observations, 1. *Set the Instrument level in that Place from which the Prospect is desired to be made ; and, with the Index at 360, direct the Telescope to some remarkable Place about the Middle of the Building, and there fix the Instrument.*

2. *The Remarks on the right Side of the Building enter in the Column of Observations on the right Hand ; and è contra.*

3. *If there be Angles both of Elevation and Depression, mark the Angles of Depression with Λ .*

The Observations of most of the Points, that need to be taken of Fig. 46. in order to protract or draw the same in Perspective, are inserted in the following Table : And observe, that, if the Building be regular, there will need but few Points to be given ; for, where you have the Height and Breadth of one Window given, with its Distance from the next, the whole Row may thereby be drawn, being all of the same Dimensions ; but Objects more irregular must be drawn by observing so many Points therein, as shall be necessary : But Practice in this Case is the best Guide.

S E C T. II.

*The Manner of Protracting these Observations,
in order to find the Points of the Building.*

Fig. 46.

		Horizon. Angles.	Vertical Angles.	
		7° : 25'	19° : 30'	a
		11 : 39	16 : 30	b
		11 : 30	8 : 30	c Δ
		19 : 20	26 : 50	d
		19 : 20	13 : 30	e Δ
		38 : 00	26 : 50	f
		38 : 00	13 : 30	g Δ
{	4	19 : 20	26 : 50	}
			25 : 30	
{	3	_____	18 : 40	}
	2	_____	9 : 35	
	Δ : 1	_____	1 : 00	
{	i	18 : 30	19 : 00	}
	e	18 : 30	22 : 40	
	u	16 : 50	17 : 50	

FIRST draw a right Line xy , Fig. 46. for the horizontal Line; and at right Angles therewith draw another Line wz , which represents the vertical Line.

Set off the Points of Distance from o , (*viz.*) from that Point where xy , and wz , intersect one another: And, according to what Bigness you would have the Plan of the Building be, make the Distance bigger or less. If you would have the Draught large, make the Distance large: *Et è contra*. There-

fore set one Foot of the Compasses at o , and with the same Extent mark the Points of Distance x, y, z .

The horizontal Angles must be drawn from the Point z , to the horizontal Line xy ; and the vertical Angles from the Points x , or y (according as the Remarks are noted on the right or left Side of the Columns) to the vertical Line wz .

The Index must be at 360 , and the Quadrant at o , when the Cross hairs in the Telescope cut the Point o on the Building: Therefore the Point o shall be the first Point of Sight on the perspective Plan.

By the Table of Observation I find, that the Index cut $7^{\circ} 27'$ on the Limb, and the Quadrant $19^{\circ} 30'$, when the Telescope was directed to the Point a : Therefore lay the Center of the Protractor to z ; and, because the Letter a is noted on the right Side of the Columns, lay the Limb on the right Side of the Line wz , the Diameter being coincident therewith; and, against $7^{\circ} 25'$, make a Mark close by the Limb of the Protractor.

Lay the Edge of a strait Ruler to the Point of Distance z , and to that Point $7^{\circ} 25'$; and where the Edge cuts the horizontal Line make a Mark.

Lay the Center of the Protractor to the Point of Distance y , (because a is noted on the right Side of the Columns) the Diameter coincident with the Line xy ; and, against $19^{\circ} 30'$ on the Limb, make a Mark.

Lay a strait Ruler to that Mark, and the Point of Distance y ; and where the Edge cuts the vertical Line wz , make a Mark at r .

Lastly, lay a parallel Ruler to the horizontal Line xy , and move it parallel thereto, till the Edge cuts the Point r in the vertical Line, and with the Compass Point draw the obscure Line $r5$.

Then lay the parallel Ruler to the vertical Line wz , and move it parallel thereto till the Edge cuts the

the Point *t*, in the horizontal Line *xy*, and by the same Edge draw an obscure Line *t g*; so shall the Intersection of these two Parallels determine the Place of the Point *a*, which was sought.

In the same Manner may the Point *b*, or any other Point be found: And then these Points, joined with right Lines, shall represent the Lines on the Building, and bear an exact Proportion thereto, according to the Rules of Perspective.

The Point *c* is found in the same Manner as *a*, only, because the horizontal Angle is the same with the Point *b*, you have no more to do but continue a strait Line from *b*, through the Point *x* in the horizontal Line, parallel to *wz*; and then lay the Center of the Protractor to *y*, with the Limb downwards; because *c* is marked with Λ (*i. e.*) under the Horizon; and draw the vertical Angle $8^{\circ} 30'$, to 8 in the vertical Line; so shall a Line drawn parallel to *xy*, from the Point 8, cut the obscure Line *bc*, at *c*, the Point sought.

The Points *b, k, l, m, n, p, q*, on the left Side of the Building, *Fig. 46.* have the same Angles with *a, b, c, d, e, f, g*, on the Right, and therefore protracted in the same Manner; excepting this Difference, that because the Points *b, k, l, &c.* are on the left Side of the Building, therefore the same Points must be found on the left Side of the vertical Line *wz*, and the Protractor laid to the Point of Distance *x*; but the horizontal Angles are all laid off from the same Point of Distance *z*.

Observe, that, in protracting these Points, it is convenient, that the Numbers on the Semicircular Protractor should be made to increase from the Diameter both Ways, that the Numbers may be counted thereon, both to the Right and Left: And then, in protracting any Point on a Building, 1. Draw the

horizontal Angle from the Point of Distance z , to the horizontal Line xy , as to t . 2. Draw the vertical Angle to the vertical Line wz , as to r . 3. Draw Lines parallel to wz , and xy , through the Points t and r ; so shall the Intersection of the two Parallels give the Point sought.

But these Points are found with much greater Expedition, if the Paper on which you draw the Plan of the Building, be fastened to a *Drawing-Board*, and the Angles laid down by the *Sector* in the following Manner:

For Example: Suppose the Point a , *Fig. 46.* was sought.

First, Draw two Lines by the Side of the *Tee*, crossing one another at right Angles, as xy , and wz . *Fig. 46.*

Take between the Points of the Compasses the Distance zo , and let the *Sector* be opened to the same Extent, by setting one Foot of the Compasses at the End of the *Tangent-Line* at 45 , on one Side of the Sector, and let the other fall at the other End of the *Tangent-Line*, at 45 , on the other Side of the Sector.

The Sector remaining at this Extent, set one Foot of the Compasses in the *Tangent-Line* on one Side of the Sector at $7^{\circ} 25'$ the horizontal Angle, as in the Table; and let the other fall at $7^{\circ} 25'$ on the other Side; this Distance set from the Point of Sight o , in the horizontal Line xy , to t .

In the same Manner take off from the Sector the vertical Angle $19^{\circ} 30'$, which set on the vertical Line wz , from o to r .

Lastly, lay the *Tee* to the *Drawing-Board*, parallel to wz , so that the Edge cut through the Point t , and draw the obscure Line tg .

Lay the *Tee* to the other Side of the *Drawing-Board* parallel to xy : And, the Edge cutting thro' the Point r , draw the obscure Line rg ; so shall the Inter-

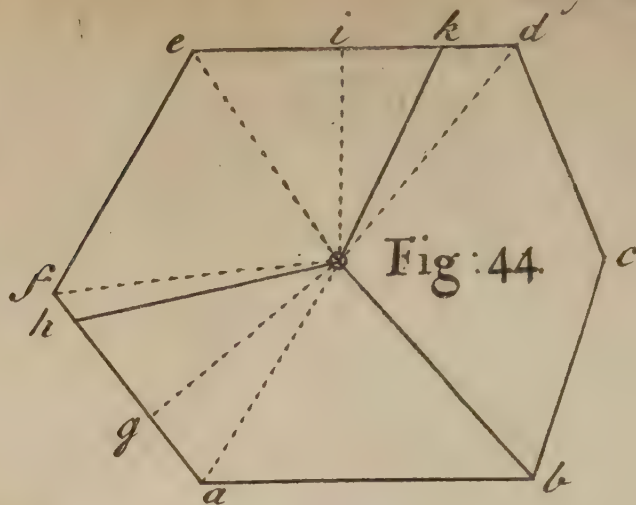
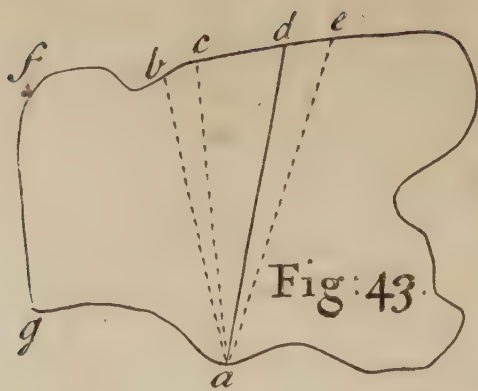


Fig: 45

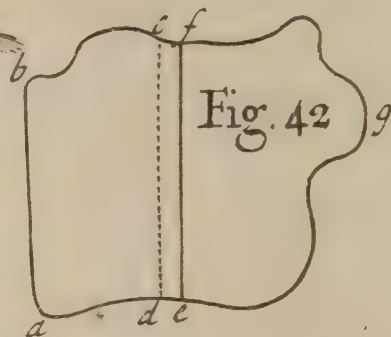
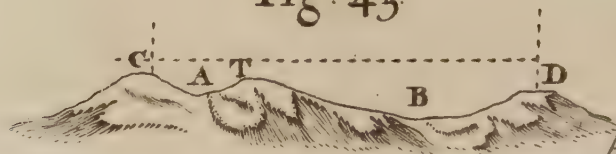
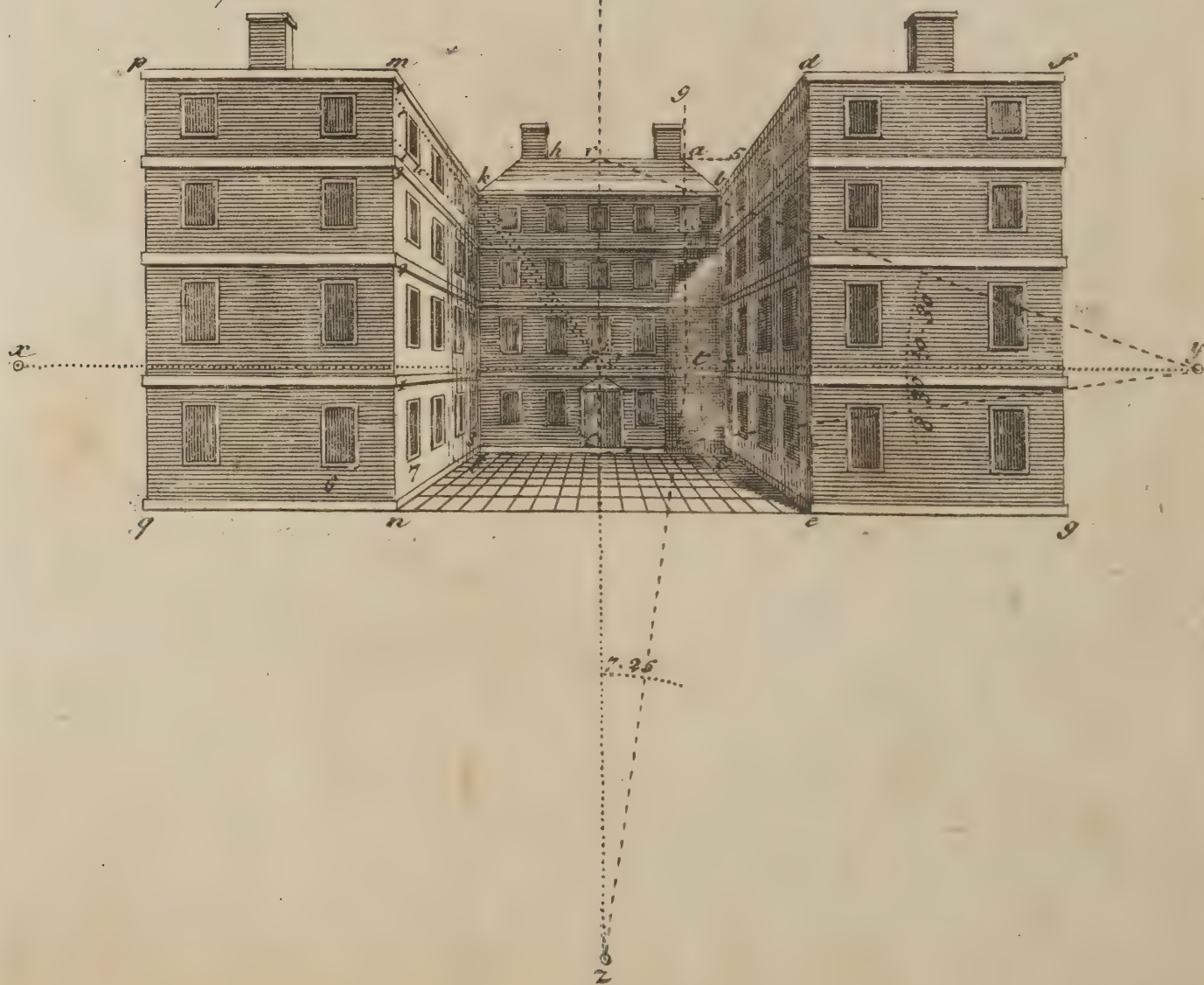


Fig: 46



Intersection of these two Lines $t\ 9$, and $r\ 5$, give the Point a , which was sought.

In the same Manner may any other Point be found in as little Time as it could be observed by the Theodolite ; but if you have not a Drawing-Board, nor parallel Ruler, you may put the Paper on the Plain Table, and, by the Edge of the Index laid on the equal Divisions, draw the Parallels ; but a Drawing-Board is better.

Having found the Points m and k , both denoting the upper Part of the Facies, if you lay a Ruler to these two Points, and continue a straight Line till it cuts the horizontal Line xy , as at f , that shall be the accidental Point (or, as the Draughts-Men sometimes call it, the vanishing Point) which being found, you may from thence draw Right-Lines to any other Points on the Draught which were viewed obliquely from z (and therefore the Figures on that Part of the Building must be made inclined on the Draught) and thereby find the Abridgment of all the Lines parallel to the Horizon on the building or geometrical Plan (which is supposed parallel to the perspective Plan or Picture.)

So when you have protracted the vertical Angles of 4, 3, 2, 1, and thereby found those Points ; you may lay a Ruler to each of them, and the accidental Point f , and thereby draw the Facies on the Wings of the Building according to their Breadth and Distance from one another on the perspective Plan or Draught.

In like Manner having found the Points e , i , and u of the first Window, you may from e and i draw Lines to the accidental Point f , which will give the Bottoms and Tops of all that Row : And then you have nothing to do but find their Breadth and Distance ; and by these Directions draw all the Windows on that Wing of the Building.

If a Statue, Coat of Arms, or other Object was placed at o , and it was desired to place the same (or another) a good deal higher, as at r ; but so, that the Object when placed at r should appear full as big as when at o , being viewed from z .

Observe with the Theodolite the Angles under which the Object appears at o ; as, if it was a Statue, observe the Height from the Feet to the Head, &c. and note the Angles with proper Remarks on a Piece of Paper; and then by directing the Telescope to r , and setting the Quadrant and Index to the same Angles, you may give Directions how to make the Object at r of such Dimensions as, being viewed from z , it will appear of the same Magnitude (or natural Height) with that at o ; & *vice versa*.

The same may be done, if Objects are desired to be placed at a Distance, to appear of the same Size as those that are nearer; with several other Problems to be performed by this Instrument, which the Ingenious will find out in the Use thereof: But I have already exceeded what I intended on this Head, and shall only add two or three Astronomical Problems, which the Surveyor perhaps may find useful in Practice.



C H A P. III.

P R O B L E M I.

*How to find a True Meridian-Line by Observing
with the Theodolite.*

THE best Time to make the Observations is in a clear Day, about 3 or 4 Hours before and after Noon.

In the Morning, having set the Instrument exactly level, move the Index horizontally, and the Quadrant vertically, till through the Telescope you see the cross Hairs in the Center of the Sun: Then observe what Degrees and Minutes are cut by the Index, suppose $3^{\circ} 25'$; which note in a Piece of Paper, as also the Angle of Elevation cut by the Quadrant.

About so many Hours after Noon, observe that the Quadrant be set exactly to the same Angle of Elevation as in the Morning; and then move the Index on the Limb till you see the cross Hairs cut the Center of the Sun, as in the Morning; and note the Degrees and Minutes which the Index then cuts on the Limb, suppose $64^{\circ} 37'$.

But *note*, 'Tis convenient in the Morning to make 3 or 4 Observations 5 or 6 Minutes from one another; because in the Afternoon you must wait till the Sun falls into the same Altitude as it had when you made the Observation in the Morning, (the Quadrant remaining at the same Angle at both) and, if it should happen to be obscured by Clouds at that Instant,
your

your Labour will be lost for that Day, having made but one Observation in the Morning.

Now, if from $64^{\circ} 37'$, the Evening Observation on the Limb, you subtract $3^{\circ} 25'$, the Morning Observation, the Remainder will be $61^{\circ} 12'$, the Half of which is $30^{\circ} 36'$; to this half Sum $30^{\circ} 36'$, add the Morning Observation $3^{\circ} 25'$, and the Sum will be $34^{\circ} 1'$.

Lastly, the Instrument remaining in the same Position, bring the Index on the Limb to $34^{\circ} 1'$, and the Quadrant and Telescope will be exactly in the Plane of the Meridian: But, if the Observation on the Limb in the Morning exceed that in the Afternoon, you must add to the Afternoon Observation 360, and work in like Manner; and, if the Remainder should exceed 360, you must subtract 360 therefrom.

Now observe what Point (on some firm Wall of a Building) is cut by the cross Hairs in the Telescope, there cause a good Mark to be fixed, or cause a Pillar with a Mark thereon to be set up by the Direction of the Telescope: Also take Notice, If you could place the Mark a quarter or half a Mile distant from the Instrument, it is better than if it was nearer. And, in making these Observations, you ought to be very exact; because, when a Meridian-Line is once well fixed, it is very useful for divers Purposes.

Observe, When the Sun is near the Tropics, the Meridian-Line may be found well enough by observing as aforesaid: But, when it is near the Equinox, there will be some Variation; because the Sun's Declination is greater or less at different Times in the same Day, and consequently, when in equal Altitudes, has different Azimuths. Therefore the Meridian-Line may be more truly found by the *Pole-Star*.

The following Table shews the Time from Noon, when the Pole Star makes the greatest Angle from the Meridian-Line towards the East, for any Time in the Year.

<i>January.</i>			<i>February.</i>			<i>March.</i>			<i>April.</i>		
D.	H.	M.	D.	H.	M.	D.	H.	M.	D.	H.	M.
1	23	16	5	20	52	5	19	8	2	17	27
8	22	51	12	20	26	12	18	43	9	17	0
15	22	17	19	19	59	19	18	17	16	16	35
22	21	48	26	19	33	26	17	52	23	16	7
29	21	20							30	15	40
<i>May.</i>			<i>June.</i>			<i>July.</i>			<i>August.</i>		
7	15	13	4	13	19	2	11	23	6	9	6
14	14	45	11	12	49	9	10	55	13	8	40
21	14	16	18	12	20	16	10	26	20	8	14
28	13	48	25	11	52	23	9	59	27	7	50
						30	9	33			
<i>September.</i>			<i>October.</i>			<i>November.</i>			<i>December.</i>		
3	7	23	1	5	42	5	3	26	3	1	26
10	6	58	8	5	16	12	2	57	10	0	54
17	6	32	15	4	50	19	2	27	17	0	24
24	6	8	22	4	22	26	1	57	24	23	53
			29	3	54				31	23	23

And, to find the Time that the Pole-Star will make the greatest Angle to the West of the Meridian, add 11 Hours 58 Minutes on the Time found in the Table. Also note, The Star comes to the same Place about 4 Minutes sooner every 24 Hours than it did the Day before.

The following Table shews the greatest Angle which the Pole-Star makes with the Meridian in any of these Latitudes, viz.

Latitude.		Angles.	
Deg.	Min.	Deg.	Min.
49	00	3	53
49	30	3	55
50	00	3	57
50	30	4	00
51	00	4	03
51	32	4	06
52	00	4	09
52	30	4	12
53	00	4	15
53	30	4	18
54	00	4	21
54	30	4	24
55	00	4	27
55	30	4	30
56	00	4	34

The Time that the Pole-Star comes to the East or West of the Meridian, and the greatest Angle which it makes therewith, being found by the preceding Table: Set the Theodolite horizontal, and bring the Index to 360 on the Limb; then turn the whole Instrument about, and elevate or depress the Telescope, till you see the Pole-Star in the Intersection of the Hairs therein, and there screw the Instrument fast: Then (if the Observation was made in the Latitude of *London*, $51^{\circ} 32'$) move the Index on the Limb $4^{\circ} 6'$, (as by the Table) towards the right Hand or Left, according as the Star is Westward or Eastward: And the Telescope will be set exactly in the Plane of the Meridian.

P R O.

P R O B L E M 2.

How to find the Latitude of any Place by the Theodolite.

THE Instrument being set level, bring the Quadrant and Telescope into the Plane of the Meridian, and let the Index remain at the same Angle on the Limb; then elevate or depress the Telescope towards the Sun, at such Time as you think it is near the Meridian, until you see the cross Hairs in the Center thereof, dividing it as it were into four equal Quarters; and observe exactly what Degrees and Minutes are then cut on the Quadrant, suppose $42^{\circ} 15'$, which note for the Sun's Meridian Altitude.

By an Ephemerides, you may find the Sun's Declination for the same Day, suppose $3^{\circ} 47'$, which if it be North Declination, subtract it from $42^{\circ} 15'$, the Meridian Altitude, and the Remainder will be $38^{\circ} 28'$, the *Co-Latitude*.

But, if the Sun hath South Declination, add it to the Meridian Altitude, and the Sum will be the *Co-Latitude*; which, subtracted from 90° , gives the *Latitude of the Place*.

P R O B L E M 3.

How to find when the Sun or any of the Stars are upon the Meridian.

HAVING the *Co-Latitude* of the Place, by the last Problem, and the Declination of the Sun given; add the Declination, if North, to the *Co-Latitude*; but, if South, subtract it, and the

the Remainder will be the Sun's Meridian Altitude for the Day, as aforesaid, which suppose to be $42^{\circ} 15'$.

Set the Quadrant to $42^{\circ} 15'$, and the Telescope will be elevated to the Meridian Altitude of the Sun ; then note the Instant of Time by a Watch or Pendulum-Clock, when through the Telescope (remaining at the same Angle) you see the cross Hairs cut the Center of the Sun ; for at that Time is the Sun upon the Meridian.

And, if you proceed in like Manner the next Day, you will have the exact Limits of the natural Day, which must exceed or want so many Seconds of 24 Hours, by your Clock or Watch, as appears by the Equation-Table for the Day, if your Clock or Watch goes right.

In the same Manner you may observe when any Star comes to the Meridian ; and, if the same Star comes to the Meridian 3 Minutes, 56 Seconds and a half, sooner the second Night than it did the first, your Pendulum-Clock or Watch keeps true Time, & *è contra*. Also if you subtract 3 Minutes, 56 Seconds and a half, for each Night after that on which you made the first Observation, you will have the true Time of that Star's coming to the Meridian for each Night following.

And thus may a Pendulum-Clock or Watch be adjusted to the mean Motion of the Sun.

PROBLEM

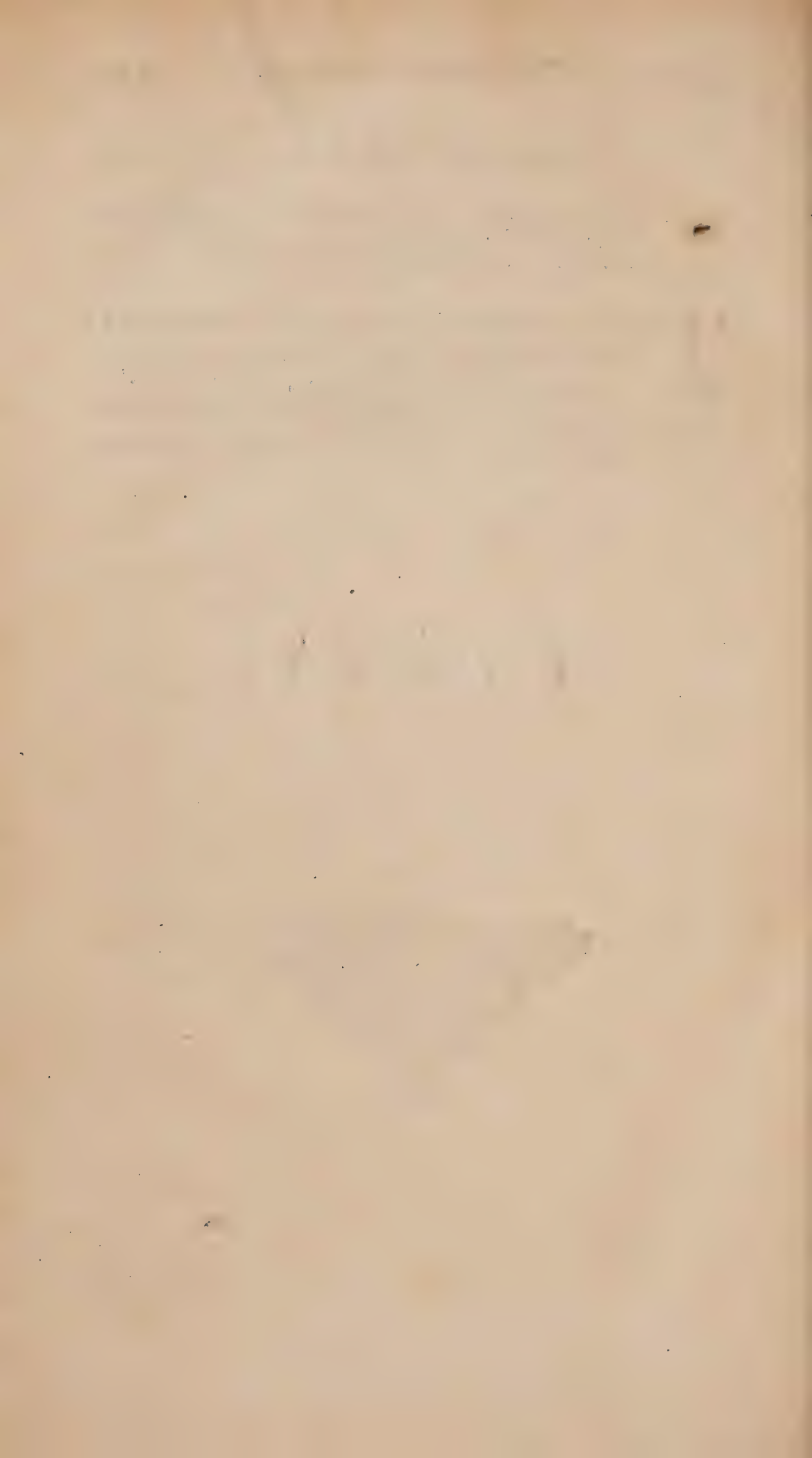
P R O B L E M 4.

How the Azimuth and Altitude of any of the fixed Stars are found by the Theodolite.

THE Instrument being set level, and exactly in the Plane of the Meridian, and there fixed, if you direct the Telescope to any Star, its Azimuth is shewn by the Index on the Limb, and the Altitude by the Quadrant, both at the same Time.

F I N I S.





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3. Wakefield's Book

